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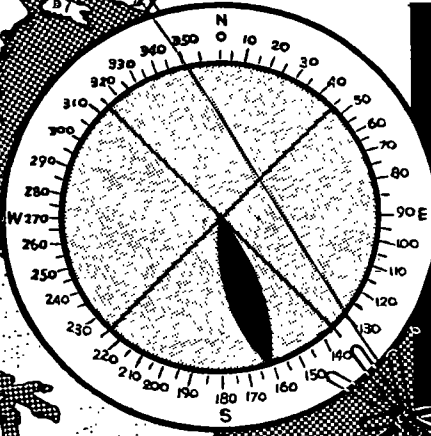
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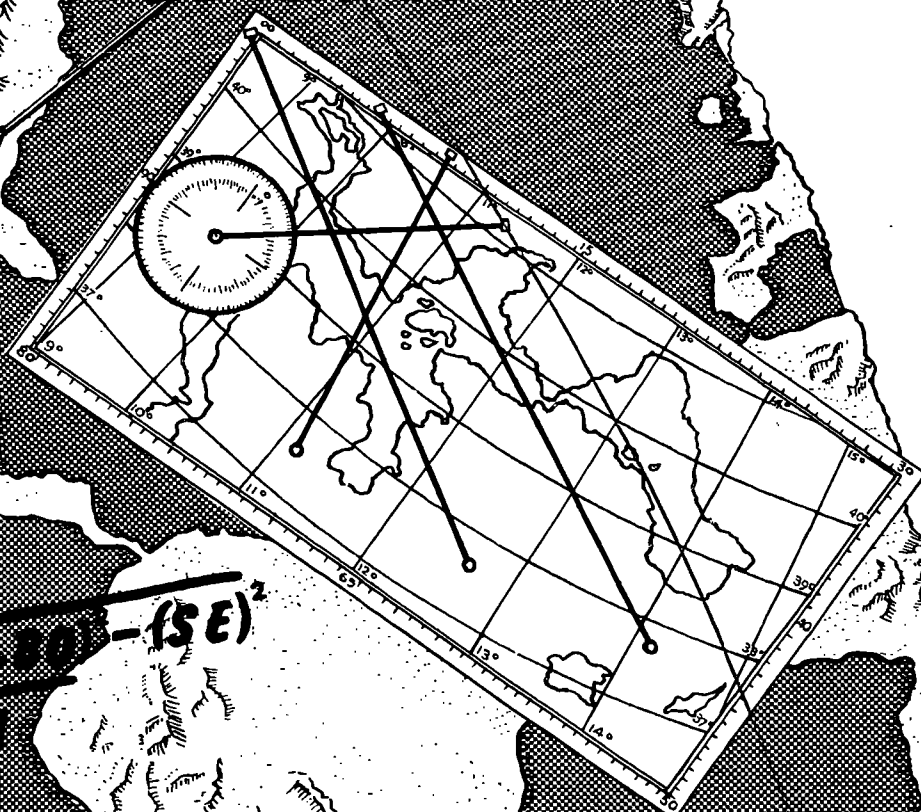
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RADIO DIRECTION FINDING



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HEADQUARTERS, DEPARTMENT OF THE ARMY

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Field Manual)
No. 30-476)

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC, 8 April 1977

RADIO DIRECTION FINDING

		Paragraph	Page
Chapter	1. INTRODUCTION	1-1	1-1
	2. WAVE PROPAGATION THEORY		
Section	I. Propagation of electromagnetic waves	2-1	2-1
	II. Polarization of radio waves	2-6	2-5
	III. Propagation factors	2-10	2-8
	IV. VHF and UHF transmissions	2-21	2-18
Chapter	3. DF SYSTEM COMPONENTS AND CHARACTERISTICS		
Section	I. Radio DF antennas	3-1	3-1
	II. Transmission lines	3-14	3-27
	III. Coupling systems for DF equipment	3-15	3-27
	IV. Bearing indicators	3-20	3-34
	V. DF receivers	3-24	3-38
Chapter	4. TYPES OF DIRECTION-FINDING EFFORTS		
Section	I. Terminology associated with DF efforts	4-1	4-1
	II. Directwave direction finding	4-2	4-1
	III. Skywave direction finding	4-9	4-10
	IV. Airborne radio direction finding	4-11	4-10
Chapter	5. DIRECTION-FINDING TECHNIQUES		
Section	I. Maps	5-1	5-1
	II. DF site requirements	5-8	5-7
	III. DF errors	5-15	5-11
	IV. Plotting methods	5-22	5-15
	V. Evaluation of DF results	5-25	5-17
	VI. Determination of fix area	5-28	5-18
Chapter	6. TASKING AND REPORTING		
Section	I. Communications requirements for DF nets	6-1	6-1
	II. Tasking authority and command structure of DF nets	6-3	6-2
Chapter	7. DIRECTION FINDING COMPUTATIONS		
Section	I. Gnomonic projection correction techniques	7-1	7-1
	II. Great circle azimuths	7-4	7-5
	III. Statistical factors	7-7	7-10
Appendix	A. REFERENCES		A-1
	B. COMMON LOGARITHMS OF FUNCTIONS OF ANGLES IN DEGREES AND MINUTES		B-1
	C. DEAD RECKONING ALTITUDE AND AZIMUTH TABLE		C-1
Glossary			Glossary 1
Index			Index 1

LIST OF ILLUSTRATIONS

Figure No.	Title	Page
2-1	Electromagnetic wave radiation from a vertical antenna	2-2
2-2	E and H fields of a radiated wave	2-4
2-3	Components of an electromagnetic wave	2-4
2-4	Representation of magnetic and electric fields in horizontally and vertically polarized wave fronts	2-6
2-5	Representation of electric and magnetic fields in wave front polarized at an angle to the horizontal	2-6

<i>Figure No.</i>	<i>Title</i>	<i>Page</i>
2-6	Vertical and horizontal components of the electric field in directions other than vertical or horizontal	2-7
2-7	Successive directions of the electric field in a circularly polarized electromagnetic field	2-7
2-8	Successive directions of the electric field in an elliptically polarized electromagnetic field	2-7
2-9	Groundwaves and skywaves	2-8
2-10	Wave penetration	2-9
2-11	Approximate heights of ionospheric layers	2-10
2-12	Reflected and direct routes for radio waves	2-11
2-13	Atmospheric ducting and refracted routes for radio waves	2-12
2-14	Wave front of normally polarized wave	2-13
2-15	Horizontal and vertical components of electric force	2-14
2-16	Vertical electric force in a wave traveling over a high-conductivity surface	2-14
2-17	Elliptical electrical force in wave traveling over a low-conductivity surface	2-14
2-18	Reflection and refraction of a light beam	2-15
2-19	Reflection of a planar wave front	2-16
2-20	Bending of a wave front by refraction	2-16
2-21	Diffraction of waves around a solid object	2-17
2-22	Multihop transmission	2-18
3-1	Polar diagram	3-1
3-2	Simple loop antenna	3-2
3-3	Circular loop antenna	3-3
3-4	Loop antenna, figure-eight response pattern	3-4
3-5	Azimuth scales	3-5
3-6	Change in loop position versus change in signal voltage	3-6
3-7	Cardioid response pattern obtained by combination of circular and figure-eight voltages	3-6
3-8	Loop and sense antenna system, relationship of voltages	3-7
3-9	Relationship of voltages in loop and sense antenna systems when the loop has been rotated 180 degrees from the position shown in figure 3-8	3-8
3-10	Cardioid response pattern	3-9
3-11	Response pattern, low sense voltage, and correct phase position	3-10
3-12	Response pattern, low sense voltage, and correct phase relation	3-10
3-13	Response pattern, proper ratio of sense, and figure-eight voltage with correct phase relation	3-11
3-14	Response pattern, high sense voltage, and proper phase relation	3-11
3-15	Response pattern, low sense voltage, and incorrect phase relation	3-11
3-16	Method of balancing antenna effect	3-13
3-17	Effects of winding arrangement	3-15
3-18	Distributed capacities in solenoidal loop	3-16
3-19	Adcock antenna, effects of vertically polarized waves	3-18
3-20	Adcock antenna, effects of horizontally polarized waves	3-19
3-21	Simple U-Adcock antenna	3-19
3-22	Shielded U-Adcock antenna	3-20
3-23	Grounded H-Adcock antenna	3-21
3-24	Balanced H-Adcock antenna	3-21
3-25	Coupled H-Adcock antenna	3-21
3-26	Balanced-coupled Adcock antenna	3-22
3-27	Effects of tilting an Adcock antenna	3-23
3-28	Common spaced-loop types	3-24
3-29	Spaced-loop antenna response patterns	3-25
3-30	Doppler direction finding	3-26
3-31	Transmitter lies along a line perpendicular to the wave front	3-27
3-32	Quasi-Doppler direction finder antenna array	3-28
3-33	Direction finding by a Quasi-Doppler system	3-29
3-34	Basic goniometer circuit	3-31
3-35	Goniometer system, directional characteristics	3-32
3-36	Typical position of azimuth scale on instantaneous indicator (oscilloscope)	3-36

<i>Figure No.</i>	<i>Title</i>	<i>Page</i>
4-1	Direct wavepath	4-2
4-2	Wave reflection and reradiation	4-2
4-3	Reradiation of transmitted signal	4-3
4-4	Groundwave DF	4-6
4-5	Concave baseline	4-7
4-6	Convex baseline	4-7
4-7	DWDF net with curving baseline	4-7
4-8	Enemy transmitter masked to friendly DF stations	4-8
5-1	Cone and cylinder, developable surfaces	5-1
5-2	Great circles	5-2
5-3	Projection of a sphere showing the arrangement of longitudes and latitudes	5-2
5-4	Diagram of the globe indicating the derivation of longitude	5-3
5-5	Diagram of the globe indicating the derivation of latitude	5-3
5-6	Mercator projection on a cylinder indicating method and showing polar distortion	5-4
5-7	Azimuthal equidistant projection centered on New York	5-5
5-8	Map of the world showing typical zones of magnetic variation	5-6
5-9	Compass rose	5-7
5-10	Declination diagrams	5-8
5-11	Field pattern	5-10
5-12	Short scatter	5-12
5-13	Long scatter	5-12
5-14	Effects of skip zone reception on bearing error	5-13
5-15	Error caused by the refraction and reflection of a radio wave	5-14
5-16	Plotting a bearing	5-16
5-17	Plotting a cut	5-17
5-18	Plotting a perfect DF fix	5-18
5-19	Three-station fix, error triangle	5-19
5-20	Error triangle solution	5-20
5-21	Angle increase comparison	5-21
5-22	Plotting using reported bearings and data base	5-21
6-1	DF net control arrangement	6-3
7-1	Spherical right triangle	7-2
7-2	Right triangle computation worksheet	7-3
7-3	Spherical triangle	7-3
7-4	GCAD computation worksheet	7-4

LIST OF TABLES

<i>Table No.</i>	<i>Title</i>	<i>Page</i>
2-1	Frequency ranges and band designators	2-1
5-1	Preferred distance from obstacles	5-9

"The word "he" is intended to include both the masculine and the feminine genders and any exceptions to this will be so noted."

This publication was prepared by the US Army Intelligence School, Fort Devens for use by personnel assigned to US Army tactical support units.

CHAPTER 1

Introduction

1-1. Purpose.

This manual prescribes basic radio Direction-Finding (DF) principles and techniques for personnel responsible for the employment and operation of DF equipment.

1-2. Scope.

This manual includes information pertaining to:

- a. Propagation of radio waves.
- b. Directional properties and types of directional antennas.
- c. Types of DF efforts.
- d. DF plotting.

1-3. Comments and Recommendations.

Users of this publication are encouraged to submit recommended changes and comments to improve the publication. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to ensure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to the Commander, US Army Intelligence School (Fort Devens), ATTN: ATSIE-TD-TS-TL, Fort Devens, Massachusetts 01433.

1-4. Concept of Warfare.

The information contained in this manual is applicable to nonnuclear warfare.

1-5. Definition, Capabilities, and Limitations of Radio Direction Finding.

a. DF is concerned with determining the arrival direction of a radio wave. Unlike an ordinary radio receiver, a DF receiver, with associated equipment, indicates the approximate direction along an imaginary line on which a distant transmitter lies. While information obtained by DF may not always be accurate enough to direct artillery fire, the direction of a distant transmitter can be determined, in most cases, to an accuracy on the order of ± 2 degrees. One DF site can determine only the approximate direction of a distant transmitter. However, by the use of two DF sites, the approximate location of a transmitting antenna can be found. By the use of three DF sites, a fixed location can be found.

b. The theory of DF has remained reasonably static since the early history of the study of electromagnetic wave phenomena. Initially, attempts were made to obtain directional transmissions because early transmitters were relatively low powered and inefficient in their output and receivers were relatively insensitive. Efforts were undertaken to "direct" the transmitted wave toward the receiving device to ensure communications rather than to determine locations. The useful applications of DF were obtained almost simultaneously with the effort to provide directional transmissions.

1-6. Military Use of DF.

DF is extensively used as navigation aids, as sources of signal intelligence, and in electronic warfare support measures.

a. Navigation. As navigational devices, DF equipment is either used alone or in combination with radio communications systems, depending upon the service which is to be provided. Such service includes the positioning, controlling, and homing of ground, sea, and air forces. DF equipment is also used by rescue personnel as an essential part of air-sea rescue. Crash beacons on downed aircraft or disabled ships provide a signal which can be located or "homed-in" on by use of DF equipment.

b. Signal Intelligence. The use of radio in military communications has increased the

value of DF in furnishing signal intelligence. Even if a hostile force is extremely careful, his transmissions by radio can be intercepted and the location of his transmitters determined. This information is invaluable when used by traffic analysts in determining order of battle.

c. Electronic Warfare Support Measures. Electronic Warfare Support Measures (ESM) are those actions taken to search for, intercept, locate, record, and analyze radiated electromagnetic energy for the purpose of exploiting such radiations in support of military operations. ESM activities provide the operational information required to conduct Electronic Countermeasures (ECM), Electronic Counter-Countermeasures (ECCM), threat detection, warning, avoidance, target acquisition, and homing.

CHAPTER 2

Wave Propagation Theory

Section I

PROPAGATION OF ELECTROMAGNETIC WAVES

2-1. General.

In order to understand how a radio receiver intercepts or "hears" signals from the atmosphere, a basic introduction to radio waves is necessary. This section describes the nature of radio waves and the basic principles involved in the propagation of radio waves from a transmitting station to a receiver or DF site. Since DF involves determination of the arrival direction of these waves, an understanding of these principles will improve the results obtained with DF equipment. If a more detailed study of wave transmission phenomena is required, additional information may be found in TM 11-666, Antennas and Radio Propagation, and TM 11-665, CW and AM Radio Transmitters and Receivers.

a. The frequency bands and their designators which are detailed in table 2-1 provide the commonly accepted limits of each band. Information which follows in this manual is primarily applicable to the DF effort on frequencies up through the High Frequency (HF) band.

b. Transmissions using frequencies in the Very High Frequency (VHF) and higher bands are identified as line-of-sight transmissions. This type of signal is used in communications and is vulnerable to DF but,

Table 2-1. Frequency Ranges and Band Designators

FREQUENCY RANGE	BAND DESIGNATOR
30 to 300 Hertz (Hz)	Extremely Low Frequency (ELF)
300 to 3000 Hz	Voice Frequency (VF)
3 to 300 Kilohertz (kHz)	Very Low Frequency (VLF)
30 to 300 kHz	Low Frequency (LF)
300 to 3000 kHz	Medium Frequency (MF)
3 to 30 Megahertz (MHz)	High Frequency (HF)
30 to 300 MHz	Very High Frequency (VHF)
300 to 3000 MHz	Ultrahigh Frequency (UHF)
3 to 30 Gigahertz (GHz)	Superhigh Frequency (SHF)
30 to 300 GHz	Extremely High Frequency (EHF)

since it uses the directwave component of the groundwave (para 2-11), it is limited in effective range. Section IV of this chapter furnishes additional information concerning higher frequency uses.

2-2. Electrical Component of Radio Waves.

a. To transmit, an antenna must be coupled to a transmitter through a coil or other electrical device. The electromagnetic wave front, or wave, which is required for transmission consists of an electrical field and a magnetic field, identified in this manual as the E and H field respectively.

b. The analogy of a pebble dropped into a smooth pond or body of water, with the resulting waves or ripples traveling in concentric circles outward from the point of disturbance, has often been used to illustrate radio wave action from a transmitter. The wave front alternately reverses polarity due to changes in the voltage applied to the antenna. Capital A, figure 2-1 illustrates this principle with the electrical lines of force at any given instant showing a positive polarity. Since electrical charges of a like polarity repel one another, these lines of force are illustrated as bowed out but shortening themselves as much as possible to the earth since they cannot expand indefinitely. When the antenna

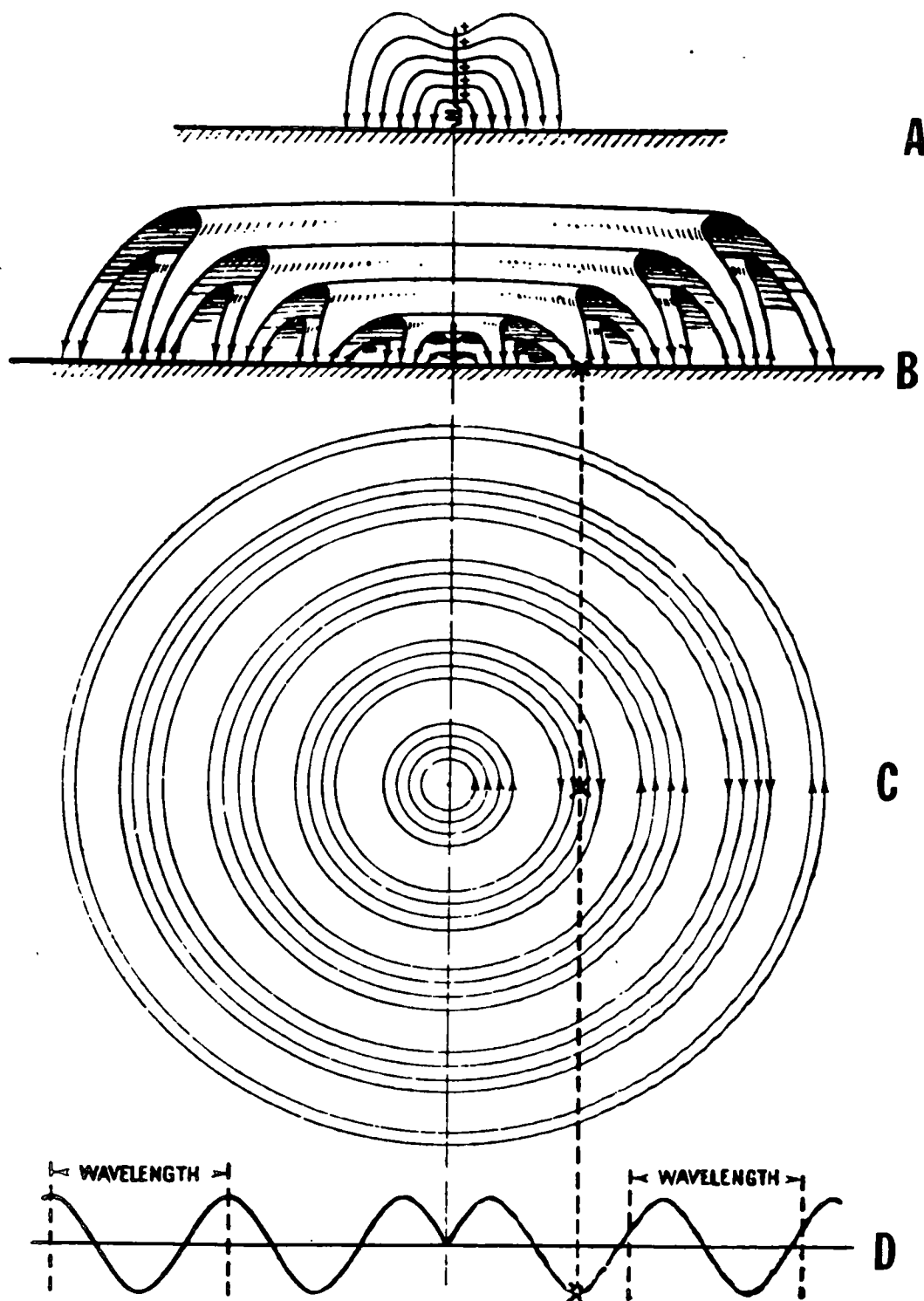


Figure 2-1. Electromagnetic wave radiation from a vertical antenna.

current changes polarity, the electrical field collapses momentarily, builds again, and assumes opposite polarity. The full cycle is illustrated in Capital B, figure 2-1. The arrowheads at the end of each line indicate the force reversing itself alternately. The electrical component of the wave continues to perform in this manner as long as the transmitter is keyed. This reversal of polarity is again observed at Capital C, figure 2-1, by the arrowheads reversing their direction periodically. Capital D, figure 2-1 equates this action to wavelength which is discussed later in this chapter. Shields, reflectors, or other devices may be attached to or installed near a transmitting antenna to make these electromagnetic waves highly directional; however, for this discussion, only omnidirectional transmissions are explained.

c. This manual does not discuss fully the electrical theory associated with electromagnetic wave propagation. To do so would involve an elaborate study of induction, flux fields and densities, right and left hand rules with regard to current flow, and many other details.

2-3. Magnetic Components of Radio Waves.

A magnetic component (H field) that cannot be dissociated from the electrical field at any time exists in the radiated wave. In paragraph 2-2, the continuing change of polarity, or oscillation, of the transmitted wave was discussed. Thus, oscillating electrical and magnetic fields are produced along the path of wave travel. The frequency of the oscillating fields is the same as the frequency of the antenna current, and the magnitudes of both fields vary continuously with this current. The variations in the magnitude of the electrical component (E field) and those of the magnetic component (H field) are in time phase, so that at every point in space the time-varying magnetic field induces a difference in voltage, which is the electric

field. Thus, the varying magnetic field produces a varying electric field, and the varying electric field, through its associated displacement current, sustains the varying magnetic field. Each field supports the other, and neither can be propagated by itself. Figure 2-2 illustrates the interrelationship of the two fields (components). It should be kept in mind that figure 2-2 illustrates only one transverse section of the entire wave front, which fills all the space shown in the figure.

2-4. Wavelength.

The conventional way of illustrating the electrical and magnetic force of any electromagnetic wave is by a sine curve, as in Capital D, figure 2-1. If a wave were visible, it would look like a sine curve, curving above and below a base line. The distance between the forces at maximum intensity in the same direction is known as the wavelength. Wavelength may also be defined as the distance between two points where the forces are identical in intensity and are changing in the same manner. Figure 2-3 is another method of illustrating the various components of the radio wave. Both elements of the wave are present regardless of polarity (which is discussed in section II, this chapter); however, all discussion and illustrations have dealt with the vertical element.

2-5. Frequency.

a. Frequency is the actual number of occurrences in one unit of time of the sine curve illustrated in Capital D, figure 2-1. The frequency of a transmitted wave is measured in Hertz (Hz), Kilohertz (kHz), Megahertz (MHz), or Gigahertz (GHz). Some existing manuals may contain frequency references using Cycles Per Second (c/s), Kilocycles (kc), Megacycles (Mc), or Gigacycles (Gc). The National Bureau of Standards and the Department of Defense (DOD) have adopted

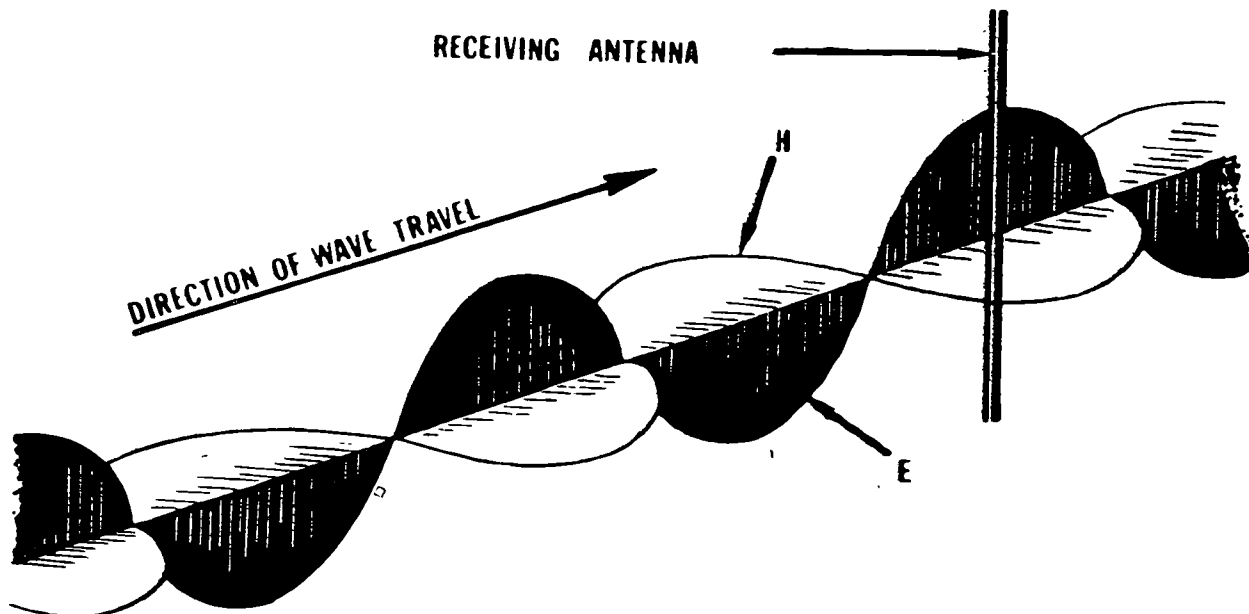


Figure 2-2. E and H fields of a radiated wave.

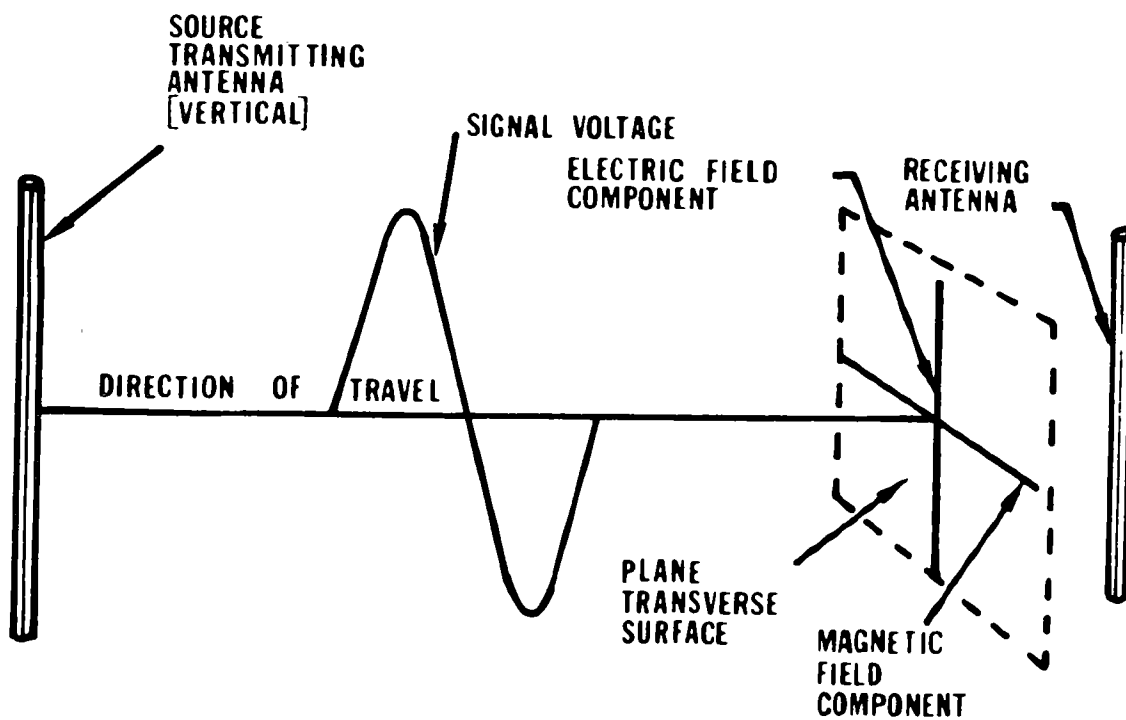


Figure 2-3. Components of an electromagnetic wave.

the term Hertz as the standard method of referring to frequency.

b. A conversion formula for wavelength and frequency is shown below. If the measurement in *Hertz* is known and a conversion to wavelength is desired, apply:

$$\text{Wavelength (meters)} = \frac{300,000,000^*}{\text{Frequency (Hz)}}$$

If wavelength (in meters) is known and a conversion to frequency (Hz) is desired, apply:

$$\text{Frequency (Hz)} = \frac{300,000,000}{\text{Wavelength (meters)}}$$

Section II

POLARIZATION OF RADIO WAVES

2-6. General.

Polarization, or the relationship of the different fields in the transmitted wave, may be either vertical, horizontal, or a mutation which adopts portions of the vertical and horizontal. The latter results in a circular or a hybrid form of a wave. This manual will deal primarily with vertical and horizontal polarization. If a whip or other vertical type transmitting antenna is used to propagate radio waves, the transmitted wave is considered to be vertically polarized. If the transmitting antenna is horizontal relative to the ground or earth's surface, the transmitted wave is horizontally polarized. The direction the electric field moves relative to the ground is taken as the reference point and determines the polarization of the wave.

2-7. Vertical Polarization.

Imagine a rope lying reasonably straight on the ground with one end attached firmly to a tree or other support. If the loose end of the

rope is raised, tightened, and given a violent up and down motion, a series of undulating "waves" will travel along the rope. Although the rope remains firmly attached and firmly grasped, the movement of the waves up and down, vertical to the ground, can be clearly observed. Radio waves perform in a manner similar to the waves produced along the rope. As long as the E field component of the waves moves up and down with reference to the earth, they are identified as being vertically polarized. Ocean waves are vertically polarized since the wave movement is up and down. There is a finite effect produced by these waves, although there is little horizontal movement of the water through which the wave passes.

2-8. Horizontal Polarization.

If the same rope had a movement applied in a horizontal manner, the waves would be in a horizontal plane and would be called horizontally polarized waves.

2-9. Plane Polarization.

From paragraphs 2-7 and 2-8, it is easy to imagine taking the same rope and giving it a violent shake in any particular angle relative to the earth resulting in a straight line, not necessarily vertical or horizontal. In all three cases, however, the wave would be polarized along a plane (plane polarized waves), a name given to any system of transverse wave motion which takes place in one plane due to the direction of propagation, whether it be vertical, horizontal, or any intermediate direction.

a. *Linear Polarization.* Vertical and horizontal polarization, illustrated in figure 2-4 are two examples of a form of polarization known as linear polarization. The term linear means that (except for the 180

*The speed of light in meters per second which is the speed at which radio waves travel.

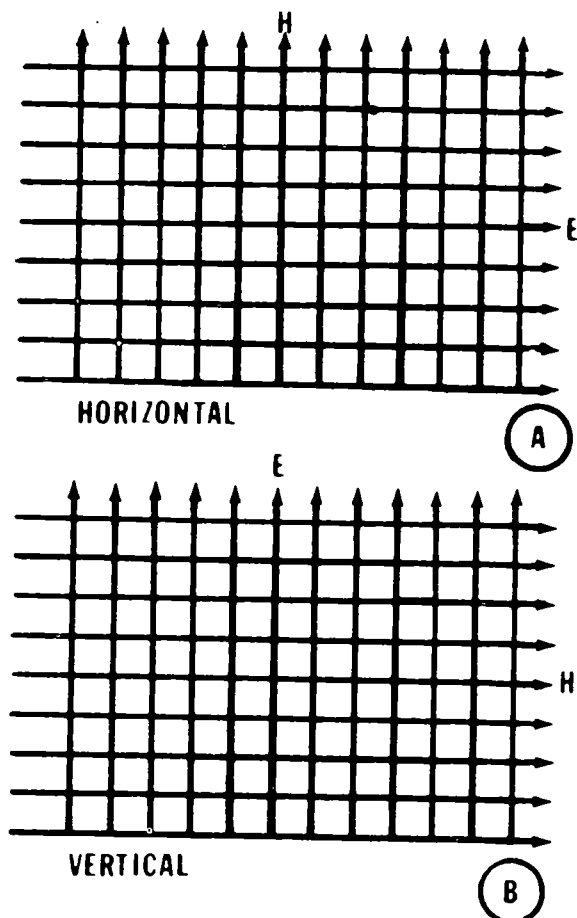


Figure 2-4. Representation of magnetic and electric fields in horizontally and vertically polarized wave fronts.

degree phase reversal during a cycle) the orientation of the electric field does not change. In other words, the electric field of a horizontally polarized wave always remains horizontal, and the electric field of a vertically polarized wave always remains vertical. By various means it is possible to produce a linearly polarized wave at any angle. A linearly polarized wave at an angle of 45 degrees from the horizontal is shown in figure 2-5. One method of producing this direction of polarization is to tilt a horizontally polarized aircraft antenna to a 45 degree angle. Tilting the electric field in this manner serves no useful purpose insofar as radiation in this form is concerned, but it can be used as a starting point for introducing another type of polarization, referred to as circular polarization.

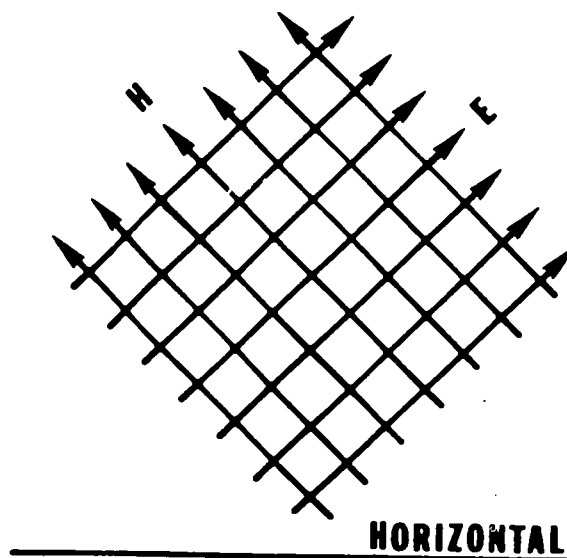


Figure 2-5. Representation of electric and magnetic fields in wave front polarized at an angle to the horizontal.

b. Circular Polarization. Assume that an electric field is tilted at a 45 degree angle as shown in figure 2-5 and further assume that by the use of some device it is possible to resolve this field into its horizontal (E_h) and vertical (E_v) components as shown in figure 2-6. These two components would still be in phase; that is, measured at a given point, both E_h and E_v would have the same relative amplitude at any given time. If either component is shifted in phase by 90 degrees, or one quarter wavelength, a new type of polarization becomes possible. If it is assumed that the horizontal component E_h has been retarded 90 degrees in phase, then when E_v has maximum amplitude, E_h is zero, and vice versa. The E vector is shown in figure 2-7 for several different conditions of E_h and E_v . To an observer standing in one spot and able to

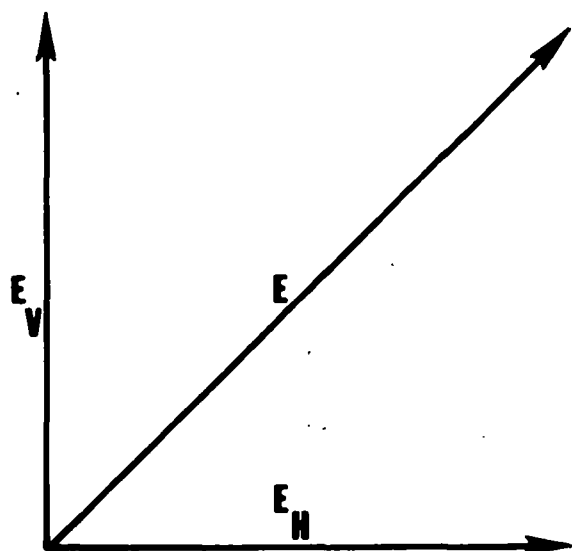


Figure 2-6. Vertical and horizontal components of the electric field in directions other than vertical or horizontal.

“see” the electric field, the field would appear to have a circular motion and a constant amplitude.

AT $E_1; E_H = O, E_V = \text{MAX POSITIVE}$
 AT $E_2; E_H = E_V, \text{ BOTH POSITIVE}$
 AT $E_3; E_V = O, E_H = \text{MAX POSITIVE}$
 AT $E_4; E_H = O, E_V = \text{MAX POSITIVE}$
 AT $E_5; E_V = O, E_H = \text{MAX POSITIVE}$

c. *Elliptical Polarization.* In the development of a circularly polarized wave, any attenuation introduced by the phase-shifting device must produce the same effect on both E_H and E_V . If this condition is not obtained, the peak amplitudes of E_H and E_V will not be the same. As a result, the electric field as “seen” by the observer will vary in both amplitude and direction, and will describe an elliptical path. Hence, the resulting polarization is known as elliptical polarization. Two possibilities of elliptical polarization are shown in figure 2-8.

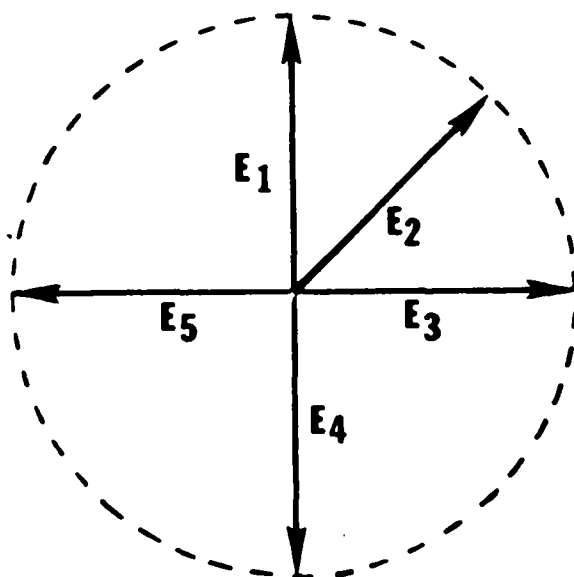


Figure 2-7. Successive directions of the electric field in a circularly polarized electromagnetic field.

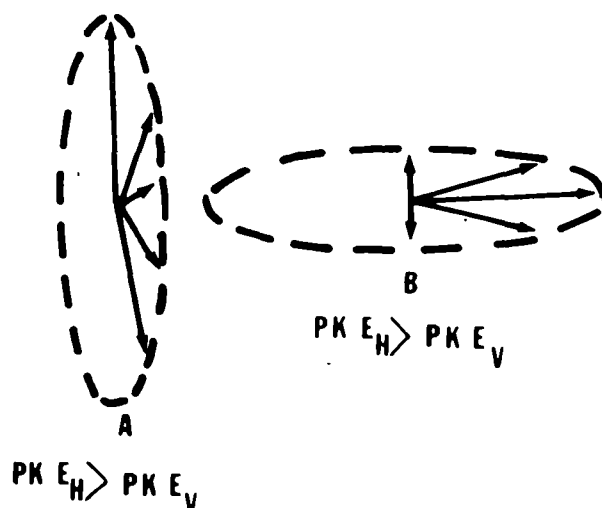


Figure 2-8. Successive directions of the electric field in an elliptically polarized electromagnetic field.

Section III

PROPAGATION FACTORS**2-10. Electrical Phenomena in Radio Wave Propagation.**

Radio wave propagation is defined as extending or transmitting electromagnetic energy through space. There are numerous factors affecting radio propagation. Wavelength, frequency, and polarization, which have been discussed previously, are all essential elements of the actual wave. Space, or the medium through which waves travel, contributes or creates additional considerations which personnel engaging in or using DF results must understand.

2-11. Types of Radio Waves.

Radio waves may be classified as either groundwaves or skywaves (fig. 2-9).

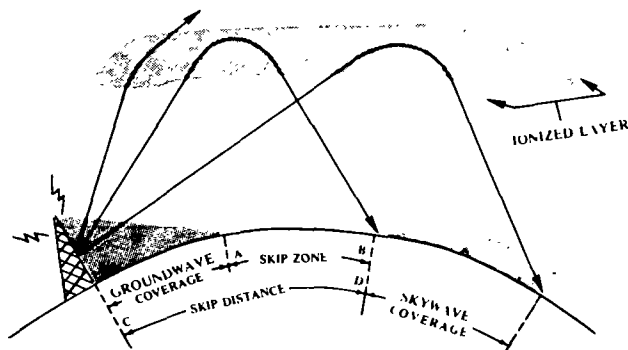


Figure 2-9. Groundwaves and skywaves.

a. Groundwaves are continuously in contact with the earth's surface and do not make use of reflection from the ionosphere. They have a tendency to be refracted and, in some cases, reflected into the lower atmosphere. At frequencies above 1500 kHz, a groundwave is affected very little by the time of day or season. The groundwave loses much of its strength and dissipates energy as

it travels over the earth's surface. However, less strength is lost when it travels over water.

b. Skywaves are transmitted upward with respect to the earth's surface. Skywaves would not be useful for communications were it not for the ionosphere, a region of ionized gases in the earth's atmosphere located some 50 to 400 kilometers above the earth's surface. Radio waves approaching the ionosphere at an angle are refracted (para 2-18) back to earth where they may be detected and used for communications purposes or for DF exploitation. Figure 2-10, similar to figure 2-9, represents the waves that penetrate the ionosphere and are lost for all practical purposes, and also those waves that return to earth for communications use.

2-12. The Ionosphere.

The ionosphere consists of a series of layers of ionized gases which occur at different levels and vary in intensity and height above the earth's surface during the course of the day. An important relationship between radio waves and the ionosphere is that the higher the frequency, the less will be its tendency to bend as it enters the ionized area. Dependent upon ionospheric conditions and the angle of the signal's arrival at the ionosphere, the bending will be so slight that the radio waves will not be sent back to earth, but will continue into space (fig. 2-10).

a. Factors which influence the ionosphere, and therefore its effect on radio waves, are the time of day, the season of the year, solar flares, magnetic storms, and certain manmade disturbances such as atomic detonations. More information may be obtained concerning this phenomena by consulting any standard reference encyclopedia and reading of the efforts of three physicists, Kennely, Heaviside, and Appleton, who were early pioneers in this area.

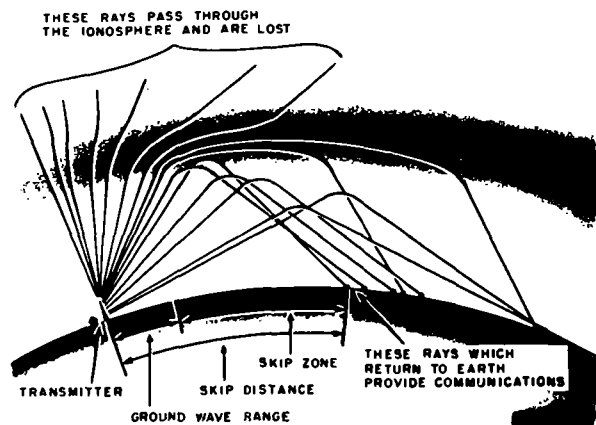


Figure 2-10. Wave penetration.

b. For the purpose of this manual, however, the reader must understand that there are essentially four layers (D, E, F1, and F2) of the ionosphere which affect communications, propagation, and DF.

(1) Some of these layers combine during periods of varying ionization. Exposure of the atmosphere to the sun causes ionization, and the degree of ionization is determined by the duration of exposure. During daylight hours, the ionization reaches a maximum intensity at approximately 400 kilometers above the earth's surface.

(2) To describe the term "varying ionization," it is necessary to briefly discuss the matter which is present in the ionosphere and the mechanics of ionization. Energy in the form of electromagnetic radiation of the proper wavelength and energy is capable of dislodging some loosely bound electrons from their atoms. When this occurs frequently in any gas, it is said to be ionized since it has atoms lacking electrons and free electrons dissociated from any atom. Atoms lacking their normal quota of electrons are called positive ions, and electrons dissociated from any atom are called negative ions. The term ion is, in fact, applied to any elemental

particle that has an electric charge. Although a few ions may exist in any gas, external energy must be applied to the atom in order to produce an abundance of ions. Ionization is said to exist when all or a large proportion of the particles in the gas are positive and negative ions. Although external energy may come from many sources, we are primarily interested in the ultraviolet rays the sun constantly gives off which ionize the gas particles of the upper atmosphere. This ionization is not static and recombination takes place continuously. The rate of recombination depends in part upon the density of the gas molecules. The atoms and ions in a gas are in constant motion, and frequent collisions take place. When an electron collides with a positive ion, it may combine with it to form a neutral atom of the gas. The time that it takes for recombination, or deionization, depends on several factors, but principally upon the average distance between the particles of the gas. If only a few particles are present, as in the upper atmosphere, collisions will not occur very frequently, and the particles remain ionized for relatively long periods.

c. Other changes in composition occur (F layers combine), and it becomes a thin layer at an altitude of approximately 270 kilometers. At night, the higher radio frequencies are more likely to penetrate the ionosphere and be lost. Therefore, as a rule, lower communications frequencies are used during the night. Conversely, during the day when the ionization of the atmosphere is more intense, higher communications frequencies can be used without undue loss of the signal because of penetration of the ionized layer. Changes in the relative proximity of the sun to the earth cause gradual changes in the ionosphere. The longer exposure of the ionosphere to the sun during the summer causes a greater degree of ionization during both night and day. Therefore, higher frequencies may be used for

summer operation. Figure 2-11 presents the approximate heights of the various layers of the ionosphere.

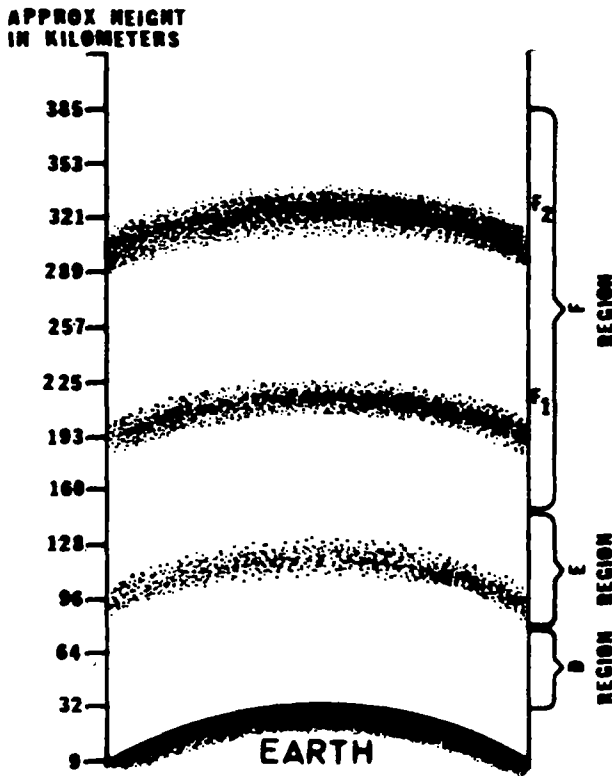


Figure 2-11. Approximate heights of ionospheric layers.

d. Remember, however, that the actual number of layers, their heights above the earth, and the relative intensity of ionization present, all vary from hour to hour, from day to day, from month to month, and from year to year. There are many ionospheric predictions generated to determine the best skywave frequencies over any transmission path at any time of day and for average conditions for the month. Ionospheric prediction information can be obtained from the Bureau of Standards. A pamphlet called the "Monthly Basic Radio Propagation Predictions" can be obtained 3 months in advance from the Central Radio Propagation Laboratories, National Bureau of Standards,

Washington, DC 20234. Information regarding radio wave propagation may also be obtained by writing to: Commander, USACEEIA, ATTN: ACCC-CED-RP, Fort Huachuca, AZ 85613.

2-13. The Stratosphere.

The stratosphere is that portion of the earth's atmosphere between the troposphere and the ionosphere. Since the temperature in this region is considered to be almost constant, it is also known as the isothermal region. The stratosphere has little if any effect on radio waves which are transmitted through it, and it is mentioned only to differentiate the three major regions of the earth's atmosphere.

2-14. The Troposphere.

a. The troposphere, which greatly influences communications, is that portion of the earth's atmosphere extending from the surface of the earth to heights of approximately 95-105 kilometers. In transmitting a wave, there are four distinct paths that the wave may take to reach the receiving antenna: direct, reflected, refracted, and tropospheric ducting. The direct and reflected paths shown in figure 2-12, are purposely exaggerated to enable the reader to clearly grasp the differences. The direct path goes directly from the transmitting to the receiving antenna. The reflected path "bounces" off the ionosphere, troposphere, or the surface of the earth at the same angle of arrival and continues to the receiving antenna. The refracted path is the path caused by the bending of the waves in the same manner light waves are bent when seen through water. If the waves are refracted by the earth, the distance they travel is severely limited due to large losses of energy in the form of heat dissipated into the earth's crust. By contrast, those waves refracted by the troposphere may travel great distances.

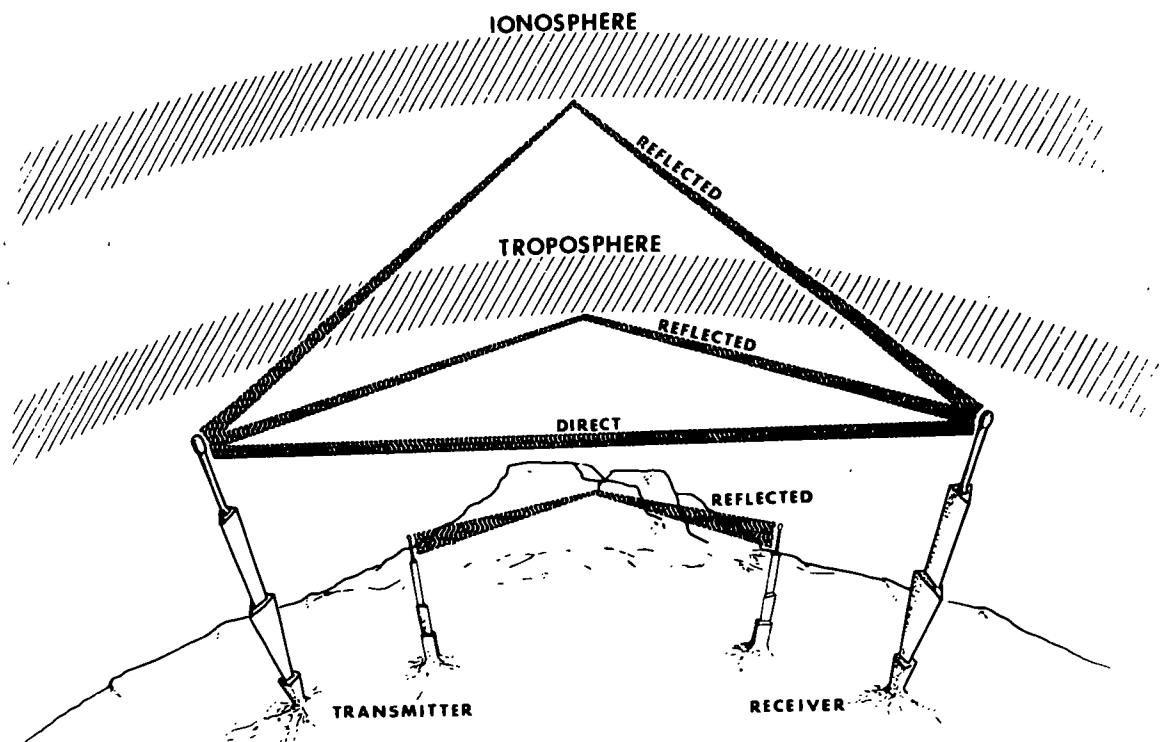


Figure 2-12. Reflected and direct routes for radio waves.

b. The tropospheric path is a combination of reflection, refraction, and certain "channeling" phenomena caused by the humidity and density of the atmosphere. The term tropospheric "scatter" is also widely used for descriptive purposes. The tropospheric wave is that component of the entire wave front which is refracted in the lower atmosphere by relatively steep gradients (rapid changes in respect to height) in atmospheric humidity, and sometimes by steep gradients in atmospheric density and temperature. At heights varying from a few hundred meters to a kilometer or so, huge masses of warm and cold air exist near each other, causing abrupt temperature differences and changes in density. The resulting tropospheric refraction and reflection make communications possible over distances far

greater than can be covered by the ordinary groundwave. Depending upon the dielectric constant and the moisture content of the troposphere, the radio waves may be refracted upward or downward, as depicted in figure 2-13. Since the amount of refraction increases as the frequency increases tropospheric refraction is more effective at the higher frequencies, providing more available communications possibilities at 50 MHz and above.

c. One common cause of tropospheric refraction is temperature inversion, which is the result of any of the following: a warm air mass overrunning a colder mass; the sinking of an air mass heated by compression; the rapid cooling of surface air after sunset; and the heating of air above a cloud layer by the

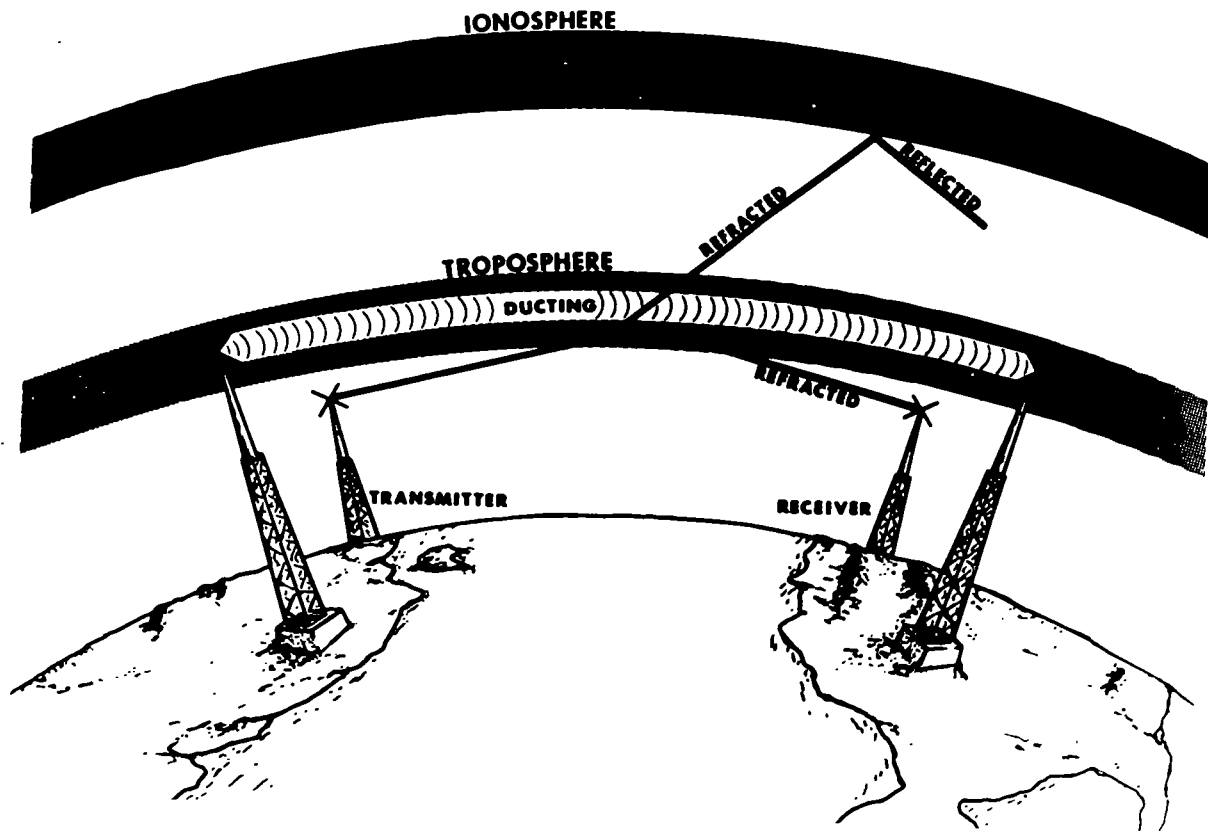


Figure 2-13. Atmospheric ducting and refracted routes for radio waves.

reflection of the sun's rays from the upper surface of the clouds. The effect of tropospheric propagation depends on weather conditions which vary from minute to minute, thus causing fading or variable field intensity. In tropospheric wave communications, the receiving and transmitting antennas should have the same polarization, since the tropospheric wave maintains essentially the same polarization throughout its travel.

2-15. Abnormal Effect of the Troposphere.

a. In the tropics and over large bodies of water, temperature inversions are present almost continuously at heights up to

approximately 1,000 meters, particularly from 50 to 150 meters. When the boundary of the inversion is defined sharply, waves traveling horizontally or at very low angles of elevation become trapped by the refracting layer of air and continue to be bent back toward the earth. Figure 2-13 shows how such a trapped wave follows a duct, the upper and lower walls of which are formed by the boundary and the earth. This is the channeling mentioned in paragraph 2-14. The waves are guided within this duct in much the same manner as in a metallic waveguide, and since attenuation in a waveguide is slight, the energy does not fall off inversely as the square of the distance. Thus, the waves follow the curvature of the

earth for distances far beyond the optical horizon of the transmitter, and in some localities they may consistently reach distances of many thousands of kilometers.

b. Tropospheric ducts also are formed by the waveguiding effect of two layers of air with sharply defined temperature inversions. The refraction from the upper boundary bends the wave down, and the refraction from the lower boundary bends the wave up, effectively trapping the energy within the layer. The height of the duct determines the minimum frequency, and if this height is only a few meters above the surface of the earth, or from boundary to boundary, transmission may be possible only at the UHF or SHF frequencies. Occasionally, the height and the dielectric characteristics of the layer are suitable for VHF transmissions. However, a necessary feature of duct transmission is that the angle of approach of the incident wave be approximately half a degree or less for the wave to be trapped. In addition, both the transmitting and the receiving antennas must be inside the duct if communication is to be established by this means. A transmitting antenna above the duct, as on a tower or promontory, will not operate into the duct, and no signals will be received by the receiving antenna. Moreover, a receiving antenna below a duct will not receive signals from an airplane flying in or above the duct, even though line-of-sight conditions prevail. From this it is apparent that accurate tropospheric propagation predictions are essential to establish reliable communications. Also, it should be obvious that due to the channeling effects of tropospheric returns, this means of communications, if used by unfriendly targets, would have little value to friendly DF efforts. Tropospheric information is included in this manual since supporting communications units make extensive use of it in normal communications, and the supported commander who receives DF information may, therefore, become

particularly attracted to this means of communications. Its value to the DF effort is of little, if any, consequence.

2-16. Influence of Soil Conductivity Relative to Wave Propagation.

A wave front is a surface of equal phase perpendicular to the direction of travel of the wave. As previously discussed, the wave front has been found to contain both electric and magnetic components as it is propagated. Within a few wavelengths of a transmitting antenna, the lines of both magnetic and electric force are appreciably curved. At greater distances the curvature becomes so slight that the network of horizontal and vertical lines becomes, for all practical purposes, a vertical plane presenting a wave front to a receiving antenna. This front is shown diagrammatically in figure 2-14. In

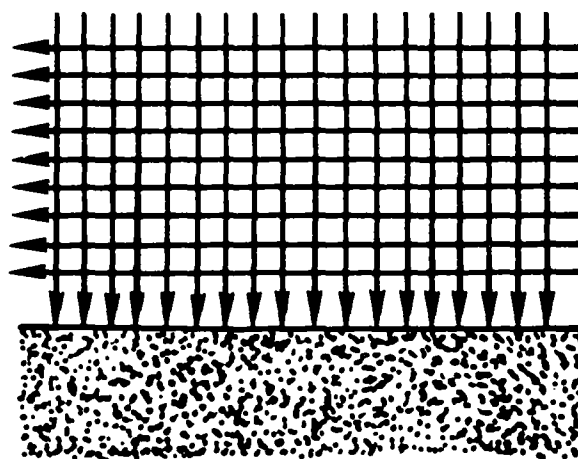


Figure 2-14. Wave front of normally polarized wave.

practice, the plane containing the electric and magnetic forces in the wave, constituting the wave front, is never truly vertical unless the wave is passing over a surface which has infinite conductivity, such as salt water, or is traveling in free space. The horizontal electric

force in a wave, in the direction of its travel, can lead to some confusion and is, therefore, worth consideration. To propose an extreme case, imagine a wave traveling over a perfect conducting surface, with the arrow AB in figure 2-15 representing the vertical

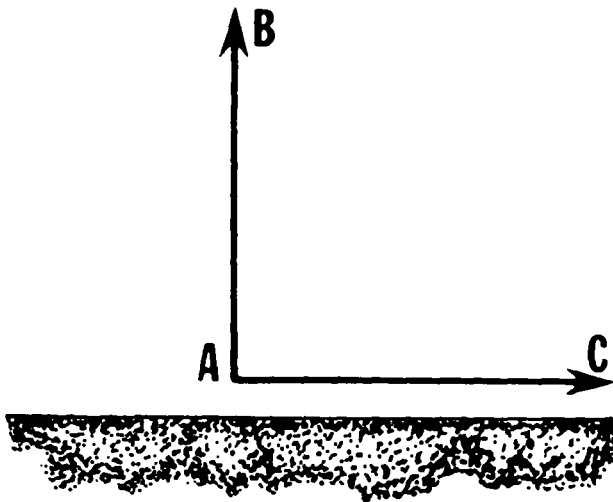


Figure 2-15. Horizontal and vertical components of electric force.

component of electric force and AC representing the horizontal component of electric force in direction and magnitude. For this to be true, there must be a potential difference between A and C. However, since the surface is a perfect conductor and has no resistance, there can be no difference of potential and likewise no lines of electric force. Therefore, AC cannot exist. The salt water of the ocean has high conductivity in this respect. Figure 2-16 shows a cross section of a wave front over the ocean with a vertical electric force being represented in direction and magnitude by the single arrow or vector AB. When a wave is transmitted over the earth's surface, with its low conductivity, there are losses into the semiconducting material which result in a horizontal component of electric force in the direction of wave travel, as shown by the two vectors in figure 2-17. The consideration becomes more

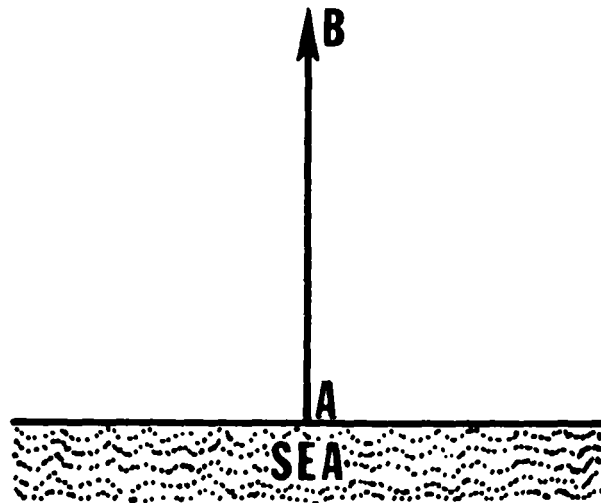


Figure 2-16. Vertical electric force in a wave traveling over a high-conductivity surface.

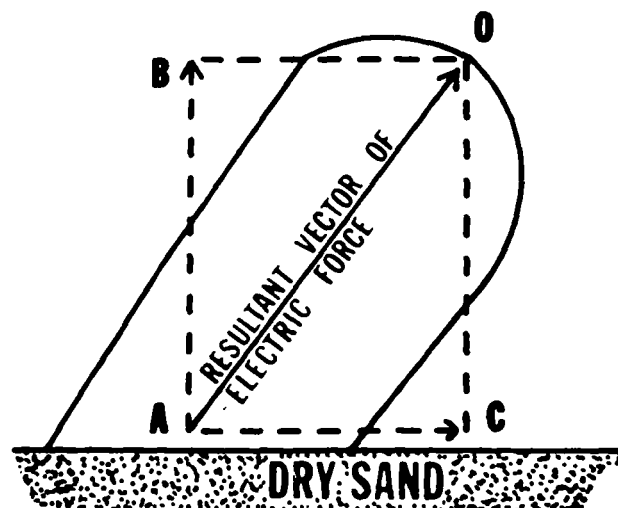


Figure 2-17. Elliptical electrical force in wave traveling over a low-conductivity surface.

complex because the vertical electrical force and the horizontal component are not usually in phase with one another, thus producing a rotating field of elliptical form, as illustrated in figure 2-17. The conductivity of the earth, or surface over which wave fronts pass, becomes very important when dealing with the different antennas used in DF operations, particularly the Adcock antenna. Although the values of conductivity and resistivity vary widely for soils of apparently similar types (they also vary with frequency), they are not appropriate to this manual.

2-17. Reflection.

When one observes himself in a mirror, the light beams or waves transmitted directly off the mirror's silver finish give the identical or "mirror" image, barring parallax or other optical distortions. Radio waves act in a similar manner to light waves, traveling at the same speed. Although light waves can be seen, radio waves must be detected by electronic equipment. Illustrations in this section will deal with both media. Figure 2-12 illustrates how radio waves are reflected off the ionosphere. Radio waves are reflected off the earth's surface, but are of little value unless the transmitting and receiving antennas are in close proximity of one another. The reflective and refractive components of light beams are illustrated in figure 2-18. The reflection of radio waves is illustrated in figure 2-19.

2-18. Refraction.

When the beam of a flashlight is directed at an angle on the smooth surface of water, some of the light will be reflected and the remaining portion will penetrate the water, as shown in figure 2-20. Refraction can also be observed by examining a glass of water into which a spoon is immersed. If viewed from an angle, the spoon appears broken or bent at the point where it enters the water because light waves travel at a slower speed through water than

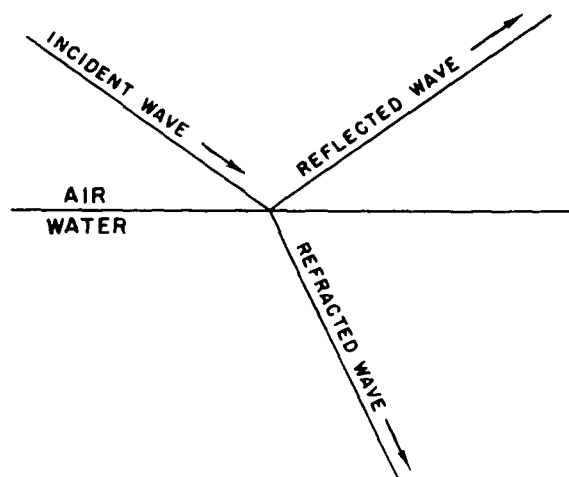


Figure 2-18. Reflection and refraction of a light beam.

through air causing a change in direction of travel of the refracted light. Figure 2-20 shows how this change in the direction of the light beam occurs. The parallel lines in this figure represent the wave front of a light beam incident to the surface of the water. Consider the wave front A-A1 (fig. 2-20), hitting the surface of the water. Since the speed of light is less in water than in air, point A will advance the distance d_1 in a given length of time, whereas point A1 will travel a greater distance (d_2) in the same length of time. As a result, the wave front will turn in a new direction. Note that refraction occurs only when the wave or beam of light approaches the new medium at an oblique angle. If the whole wave front arrives at the new medium at the same moment (perpendicularly), it is slowed uniformly and no bending occurs.

2-19. Diffraction.

If a beam of light in a dark room shines on the edge of an opaque screen, it will not form a perfectly outlined shadow because the light rays bend around the edge of the object, decreasing the area of total shadow. The diffraction or bending of a light wave around the edge of a solid object is slight. The lower

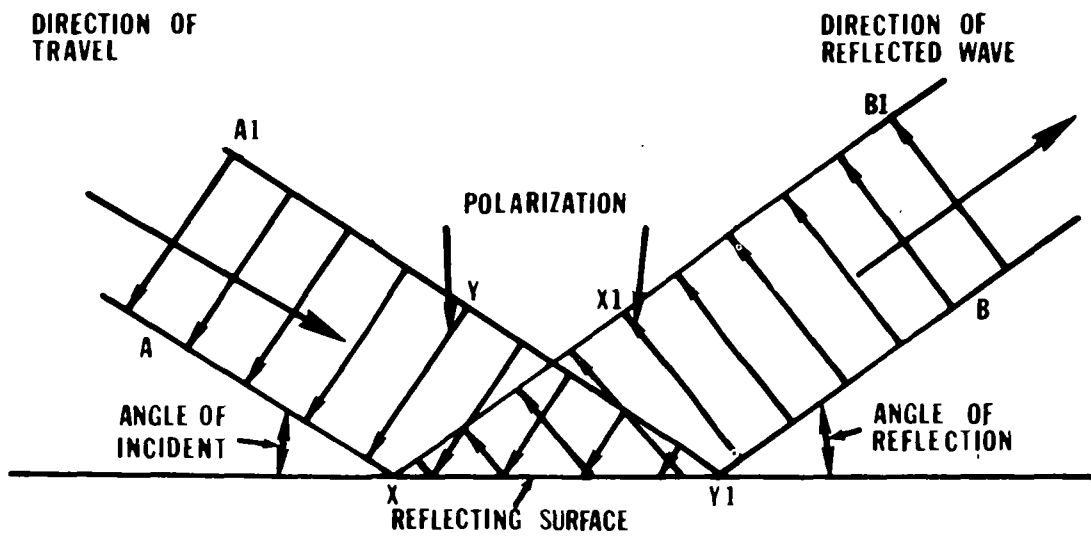


Figure 2-19. Reflection of a planar wave front.

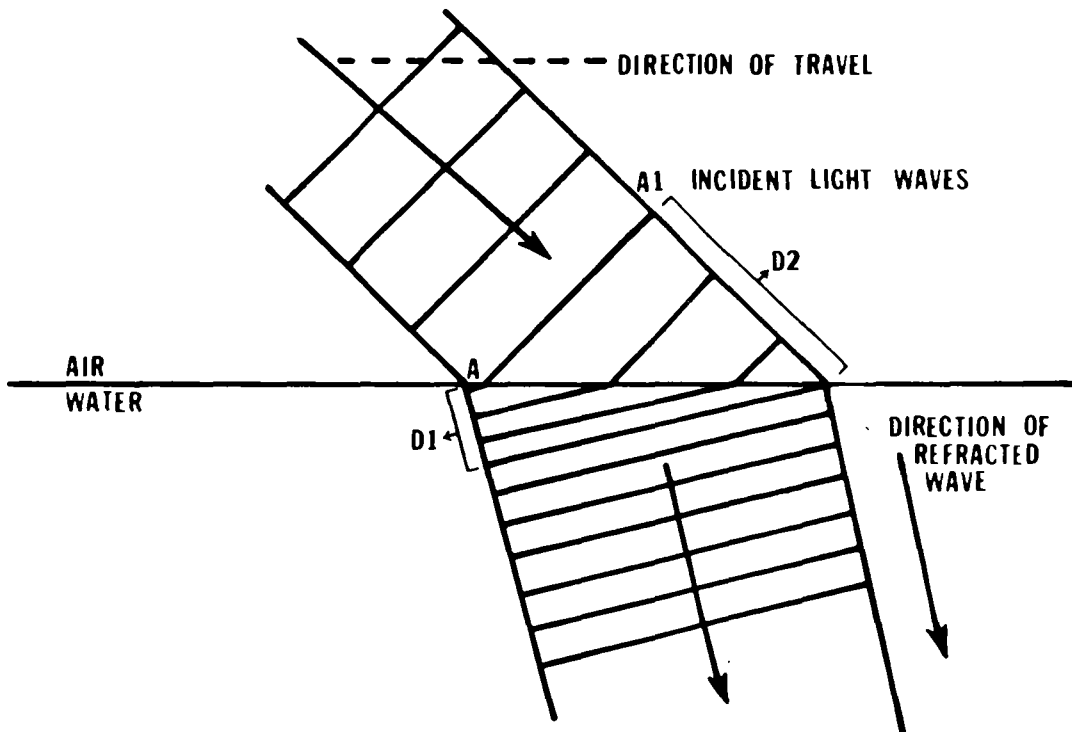


Figure 2-20. Bending of a wave front by refraction.

the wave frequency, or the longer the wavelength, the greater the bending of the wave. Therefore, radio waves are more readily diffracted than light waves, and sound waves more than radio waves. Figure 2-21 illustrates why radio waves of the proper frequency can be received on the far side of a hill or other natural obstruction, and why sound waves can be heard readily around the corner of a large building. Diffraction is an important consideration in the propagation of radio waves over long distances because the largest object to be contended with is the curvature of the earth, which prevents a direct passage of the waves from the transmitter to the receiver.

2-20. Skip Zones and Skip Distances.

In the foregoing discussion on propagation factors, the skip zones and skip distances have

been illustrated, although not explained. Simply stated, the skip zone is that area in which the groundwave can no longer be detected (area AB, fig. 2-9) and the skywave has not yet returned to earth after being reflected or refracted off the ionosphere or troposphere. The wave front has "outrun" the groundwave portion, and the skywave portion has not returned to earth after reflecting off the ionosphere. The skip distance is that area where no skywave reception will normally be possible (area CD in fig. 2-9) since the wave has not returned to earth after its first or subsequent bounce off the reflecting layer. Depending upon the frequency and the transmitter power, multihop transmissions are routinely used for communications; there will be, however, skip distances between the points of the waves' return at each hop. Figure 2-22 illustrates multihop transmissions.

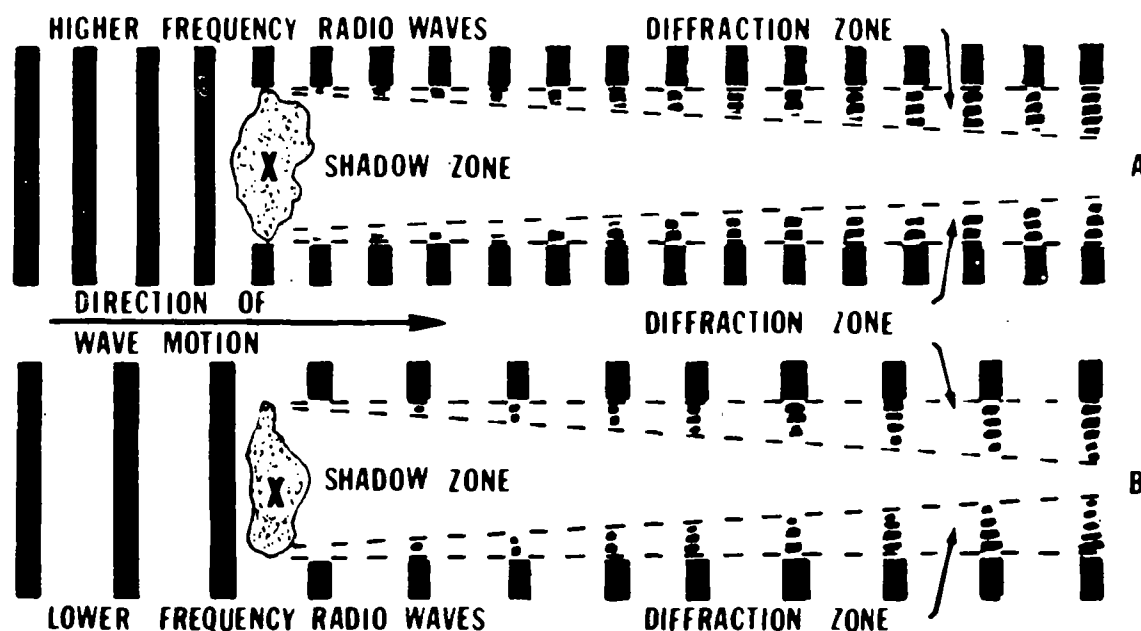


Figure 2-21. Diffraction of waves around a solid object.

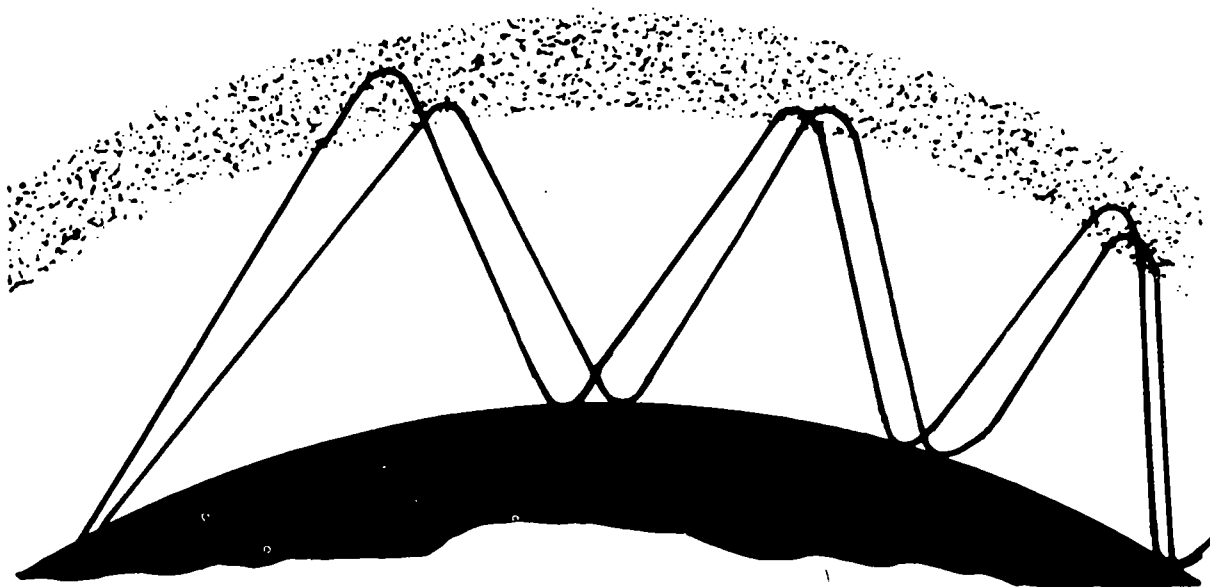


Figure 2-22. Multihop transmission.

Section IV

VHF AND UHF TRANSMISSIONS

2-21. VHF Transmissions.

The majority of all Frequency Modulated (FM) communications links operate within the frequency range of 30 to 300 MHz, (VHF band). Several FM radio sets are employed by US forces with speech security devices. This equipment provides secure communications in a wide variety of tactical situations. The planning range for this VHF equipment, with the transmitter and receiver located at ground level and no intervening hills, buildings, towers, or similar obstructions, is approximately 32 kilometers from a fixed location and 24 kilometers if moving. By increasing the height of the receiving antenna (as in an airborne platform) above the ground, it is readily apparent that the usable range of VHF signals for DF operations is greatly

increased. This portion of DF application is covered more fully in section IV, chapter 4, of this manual.

2-22. Secondary DF Applications of VHF Transmissions.

Particularly in helicopters or other slow, low-flying aircraft, the "homing" use of VHF transmissions is important. When weather conditions deteriorate and visibility is marginal, the aircraft commander, copilot, or observer may use a homing antenna or homing adaptor. By tuning the receiver to a known friendly frequency in the VHF band, having that station key its transmitter for extended periods (20-30 seconds), and rotating the antenna for a null, the general direction of the transmitter can be determined. This method will be explained in paragraph 3-1. By flying the aircraft in the direction indicated by the null, the VHF

signal becomes a ground navigational aid. Although this is DF homing instead of target locating, it is another useful application of the principles of DF.

2-23. UHF Transmissions.

Equipment is undergoing research and development, and in some cases field testing, for UHF DF applications. Since the principles and systems for UHF will be similar to those employed in VHF, they will not be discussed here.



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CHAPTER 3

DF System Components and Characteristics

Section I

RADIO DF ANTENNAS

3-1. Polar Diagram of Antennas.

In the study of DF, it is convenient to have some method of illustrating the receiving sensitivity of an antenna system for various angles of arrival of an incoming wave. A method to illustrate this for both transmitting and receiving antennas is the polar plane diagram.

a. In figure 3-1, the plus mark at the zero point represents the directive antenna system of a receiver. To indicate the antenna sensitivity (response pattern) for signals arriving from different directions move a portable transmitter in a circle around the antenna, keeping the transmitter power output and distance from the receiving antenna constant. Measure the receiver input and compare with the transmitter output at known angles (0, 10, 20 degrees, etc.). If radial lines are drawn from the central point with each line corresponding to the azimuth for which the receiver input was measured, and if the lengths of these lines correspond to the receiver input voltages, the curve obtained

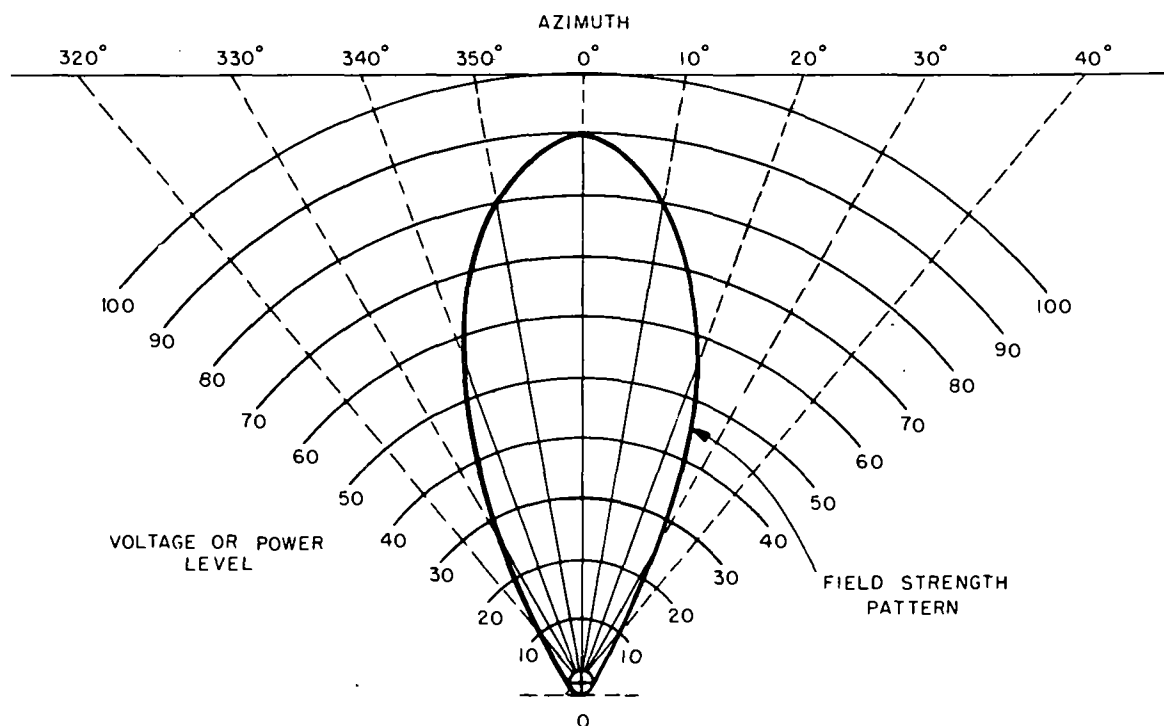


Figure 3-1. Polar diagram.

by joining the extremities of all these lines will give a clear picture of the directional properties of the antenna system. For example, in figure 3-1, the level of receiver input is 80 volts at 10 degrees, 69 volts at 15 degrees, 56 volts at 20 degrees, 27 volts at 30 degrees, etc.

b. When the polar diagram of a directional transmitting antenna is made, the process is reversed so that the receiver circles the antenna. In either case, the transmitter output and the receiver gain must be kept constant during the test so that the measured signal strength changes only because of directivity.

3-2. Loop Antennas.

Loop antennas are as old as radio itself. Heinrich Hertz used them in his original experiments with radio transmission and reception, and their directional properties were known long before there were enough radio transmitters to make direction finding worthwhile. A loop antenna consists of one or more turns of conductor, either self-supporting or wound on an insulated frame. The most commonly used styles are square (fig. 3-2) or circular (fig. 3-3) loops. The loop in figure 3-2 is illustrated as one turn of wire.

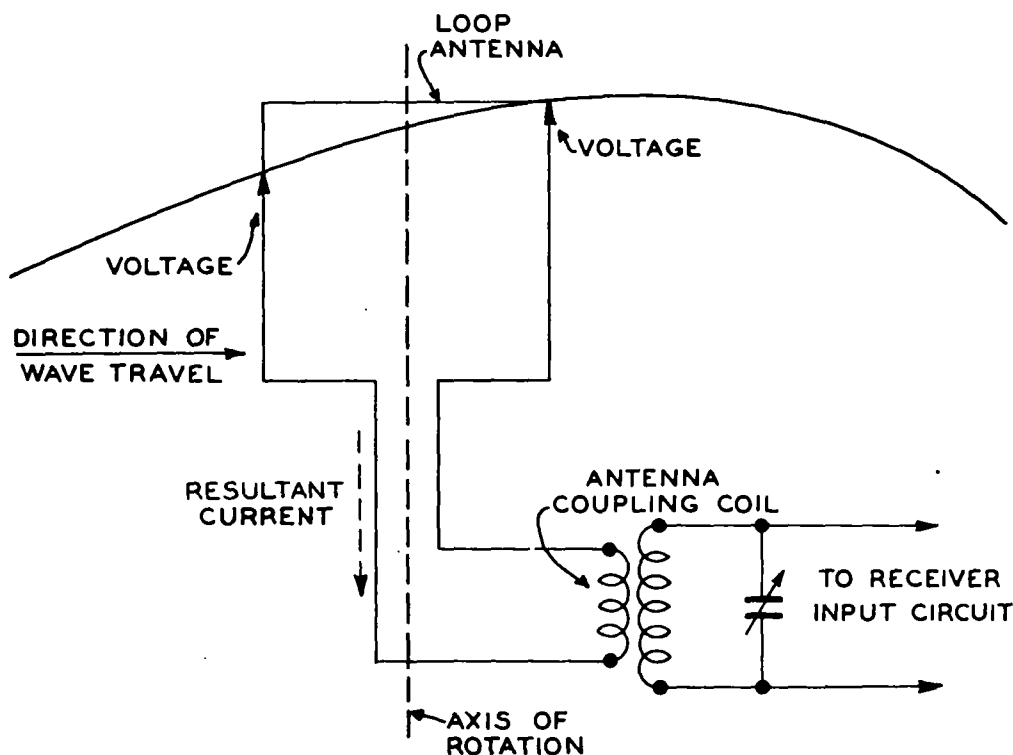


Figure 3-2. Simple loop antenna.

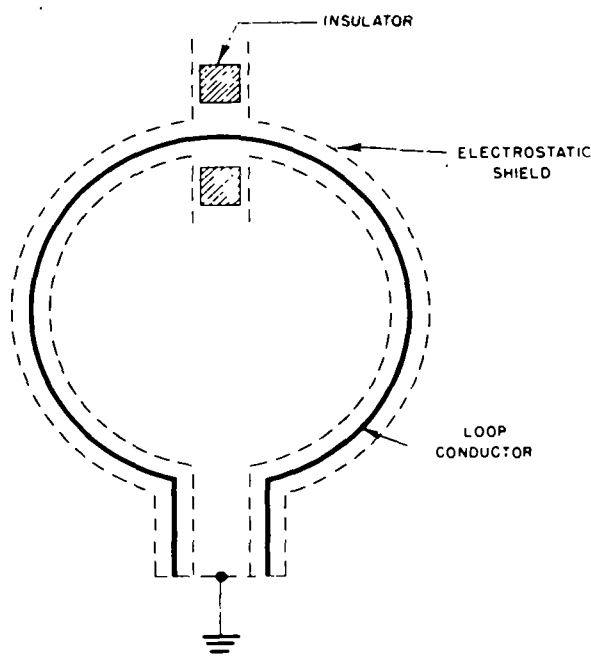


Figure 3-3. Circular loop antenna.

a. *Maximum Reception.* Consider the loop placed in the path of a vertically polarized wave with one side of the antenna closer to the transmitter than the other. With the plane of the loop parallel to the direction of wave travel the wave front reaches the vertical sides at slightly different times. Since wave polarization is spoken of in terms of the electric field, the magnetic component of a vertically polarized wave is horizontal (see fig. 2-2). This horizontal magnetic component induces voltages in both vertical arms of the loop but not in the horizontal arms since the wave travels parallel to them. The voltages induced in the vertical arms partly cancel each other across the antenna coupling coil because the amplitudes of the induced voltages differ at any given instant of time. The resultant voltage has a relative magnitude proportional to the field intensity of the wave.

b. *Minimum Reception.* If the loop is rotated about a central vertical axis until it is broadside to the oncoming wave (perpendicular to the direction of wave travel), the voltages induced in the vertical arms are equal and in phase, and will cancel across the antenna coupling coil to give minimum reception. This point of minimum response is called a null.

c. *Pattern with Normal Polarization.* When the incoming radio waves are vertically polarized, the condition under which a vertical loop would be used for direction finding, the loop antenna has a figure-eight response pattern. In figure 3-4, the loop appears in the 90-270 degree position; any signal received from either of these directions will induce maximum signal into the receiver. As the loop is turned away from the direction in which the wave is arriving (90-270 degrees), the received signal decreases, reaching a minimum when the loop is in either the 0 or 180 degree position. The line of direction (bearing, azimuth) to a transmitter can be determined by rotating the loop on its vertical axis until either a null or a maximum signal is produced. The transmitter direction will be broadside to the loop at the null or edgewise to the loop at the maximum. The appropriate direction will be indicated by an azimuth scale attached to the loop (fig. 3-5). It is customary to use the minimum rather than the maximum output of a loop when finding an azimuth since it permits a sharply defined indication and greater accuracy. The response pattern in figure 3-6 demonstrates the reason that this is so. In this instance, a maximum response of 100 microvolts (uv) is obtained with the loop edgewise to direction A (toward the transmitter). With the loop pointing toward B, a 10 degree rotation, there is only a 1.5 microvolt change in signal strength; this difference is not noticeable in the receiver input. But with the loop broadside to a transmitter at D, a null position, a similar 10

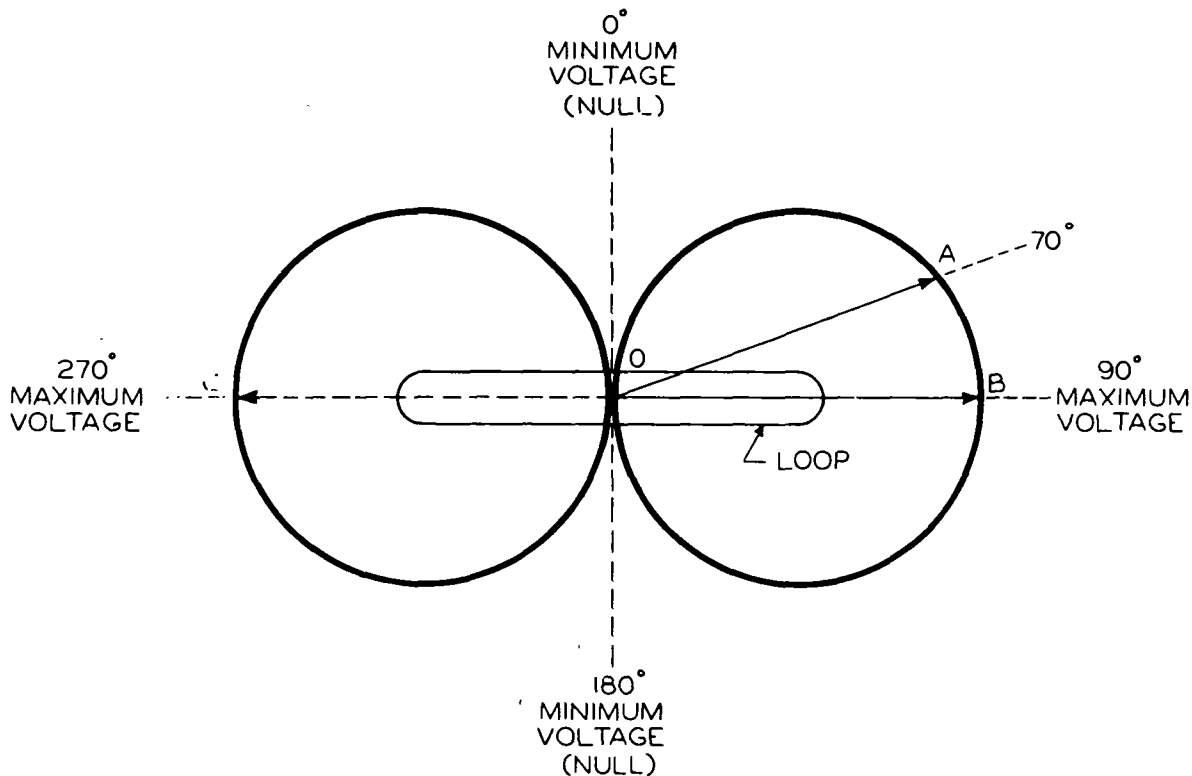


Figure 3-4. Loop antenna, figure-eight response pattern.

degree rotation causes a 17.4 microvolt change in signal intensity.

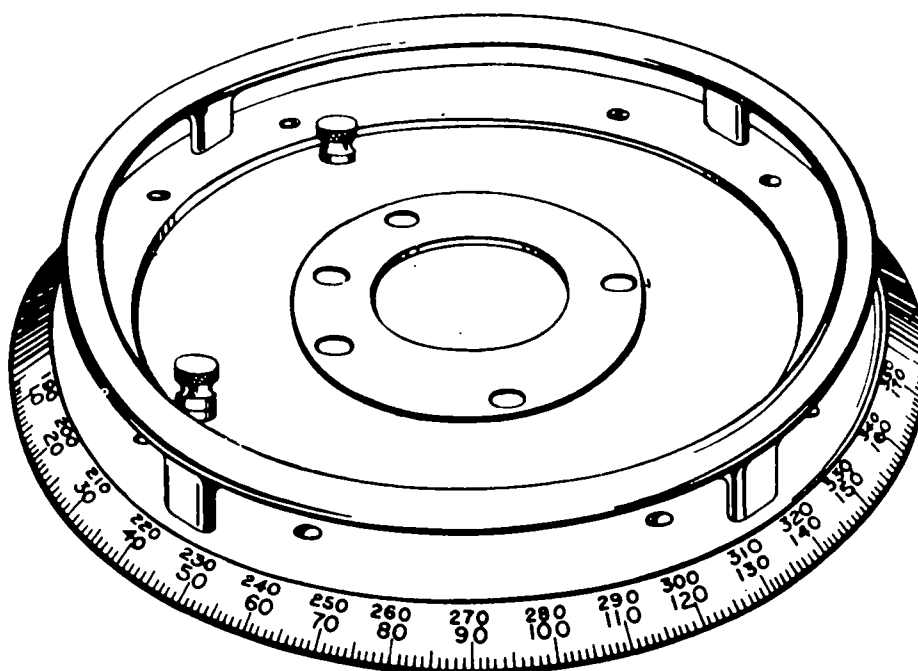
d. Pattern with Abnormal Polarization. Since vertical polarization is considered normal, any horizontally polarized wave is considered to be abnormally polarized for the simple loop direction finder. A horizontally polarized wave has no effect on vertical conductors, but it will induce voltage in horizontal conductors such as those at the top and bottom of a loop. For DF purposes, these horizontal conductors are considered to be ineffective and any induced current is considered inconsequential.

e. Ambiguity. Unless the general direction of the transmitter is known, a direction finder equipped with a simple loop

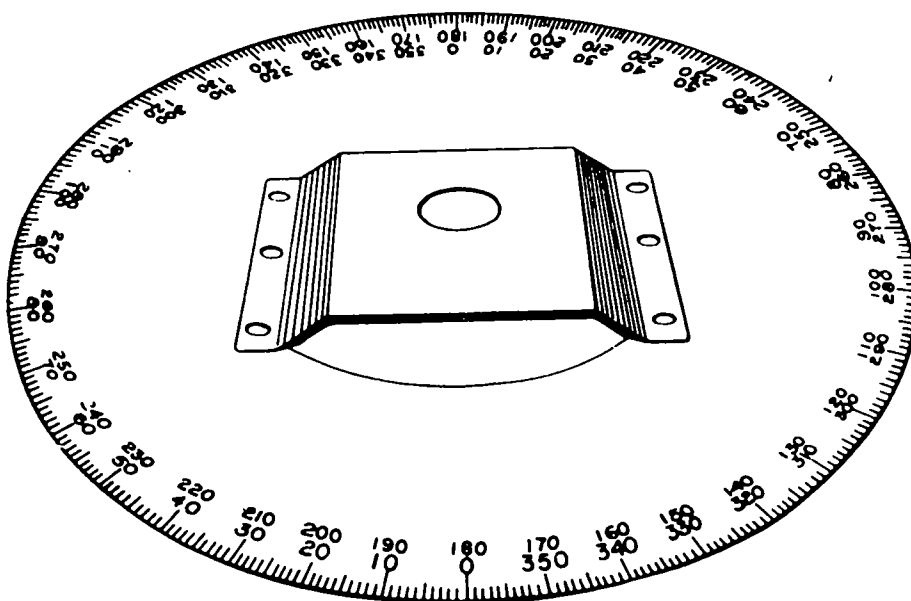
antenna cannot determine whether a transmitter lies forward of or behind the direction finder. This 180 degree ambiguity is caused by the two null positions of the loop. Without a sense antenna or sensing circuit, there can be no indication which of the two directions is the correct azimuth.

3-3. Loop and Sense Antennas.

a. Purpose. The sense antenna is usually an omnidirectional vertical whip or monopole placed at the vertical axis of the loop. Both the circular response pattern of the sense antenna and the figure-eight pattern of the loop are symmetrical, but when properly combined the two antennas produce a lopsided or unidirectional pattern (the cardioid pattern or "valentine-shaped heart"



COUNTER CLOCKWISE SCALE



CLOCKWISE SCALE

Figure 3-5. Azimuth scales.

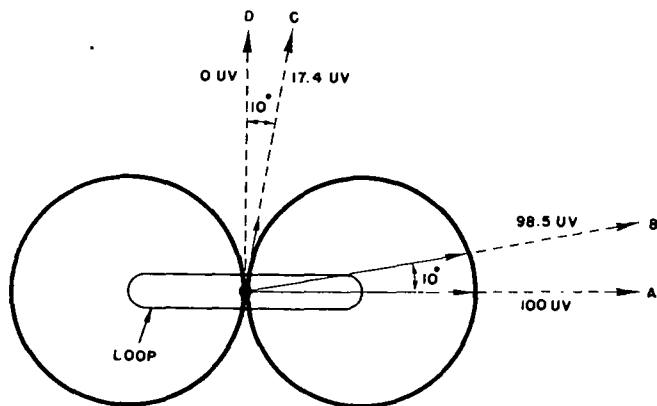


Figure 3-6. Change in loop position versus change in signal voltage.

in fig. 3-7). The large end of this pattern lies to the right of one null and to the left of the other null of the figure-eight pattern. By observing the relative position of the unidirectional pattern, the two nulls can be distinguished, thus resolving the 180 degree ambiguity of the simple loop. One null is

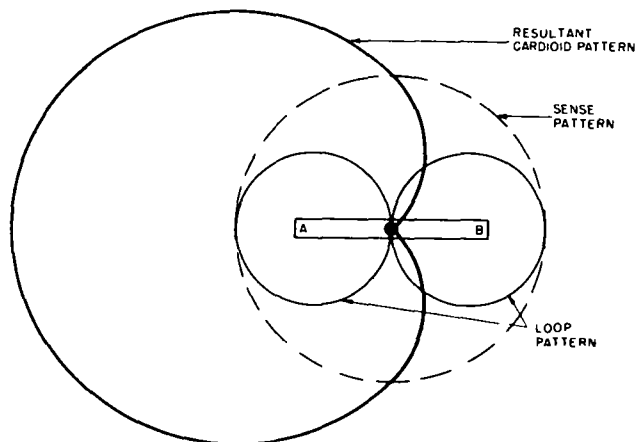


Figure 3-7. Cardioid response pattern obtained by combination of circular and figure-eight voltages.

arbitrarily designated as the front or direct null, while the other is called the back or reciprocal null.

b. Application. After the loop has been turned to a null, the direction may either be read from an azimuth scale or observed directly. The sense antenna is then placed in operation to change the response pattern from a figure eight to unidirectional. The null vanishes due to this change. Upon turning the loop 90 degrees to either side from the former null position, the response is found to be greater on one side than on the other. Which side is greater depends on whether the loop originally had the direct null facing toward or away from the transmitter. As a rule, if the response increases as the loop is turned clockwise, increasing the azimuth scale reading, or if the response decreases as the azimuth reading decreases, the direct null was toward the transmitter. If the response changes in the opposite direction, the reciprocal null was toward the transmitter. This relationship is not always used. It can be reversed by transposing connections in the antenna circuit to reverse the relative polarity of loop and sense antennas, or by a 180 degree shift in the position of the azimuth scale or pointer relative to the loop. There are cases in which such a reversal has been made intentionally.

3-4. Cardioid Theory.

When the voltages from the loop and sense antennas are combined with the proper relative phase and amplitude, the resulting pattern is a heart-shaped curve known as a cardioid. A typical case is illustrated in figures 3-8 and 3-9.

a. A radio wave traveling past the loop, as indicated in capital A, figure 3-8, strikes leg No. 1 a short time before it strikes leg No. 2.

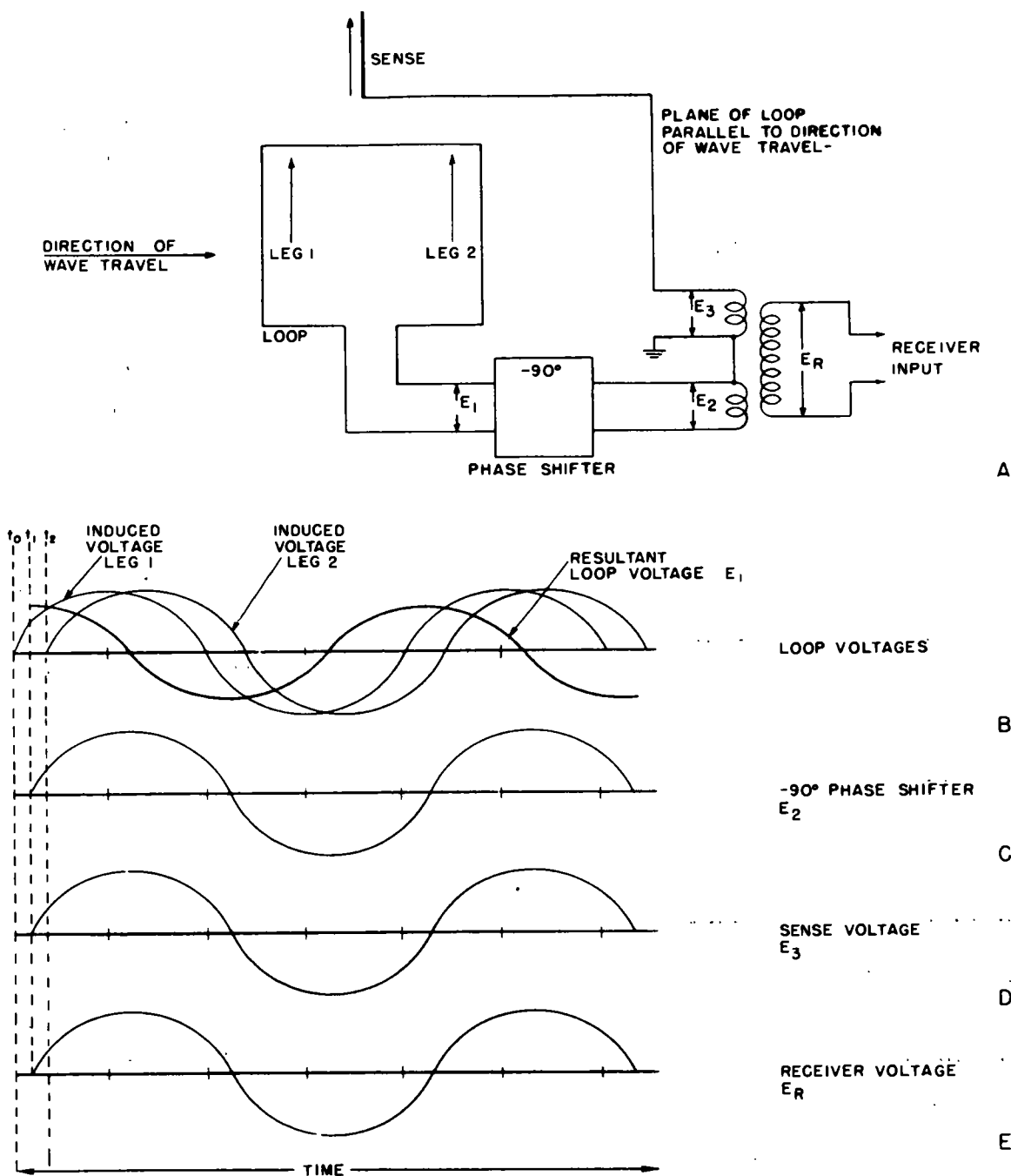


Figure 3-8. Loop and sense antenna system, relationship of voltages.

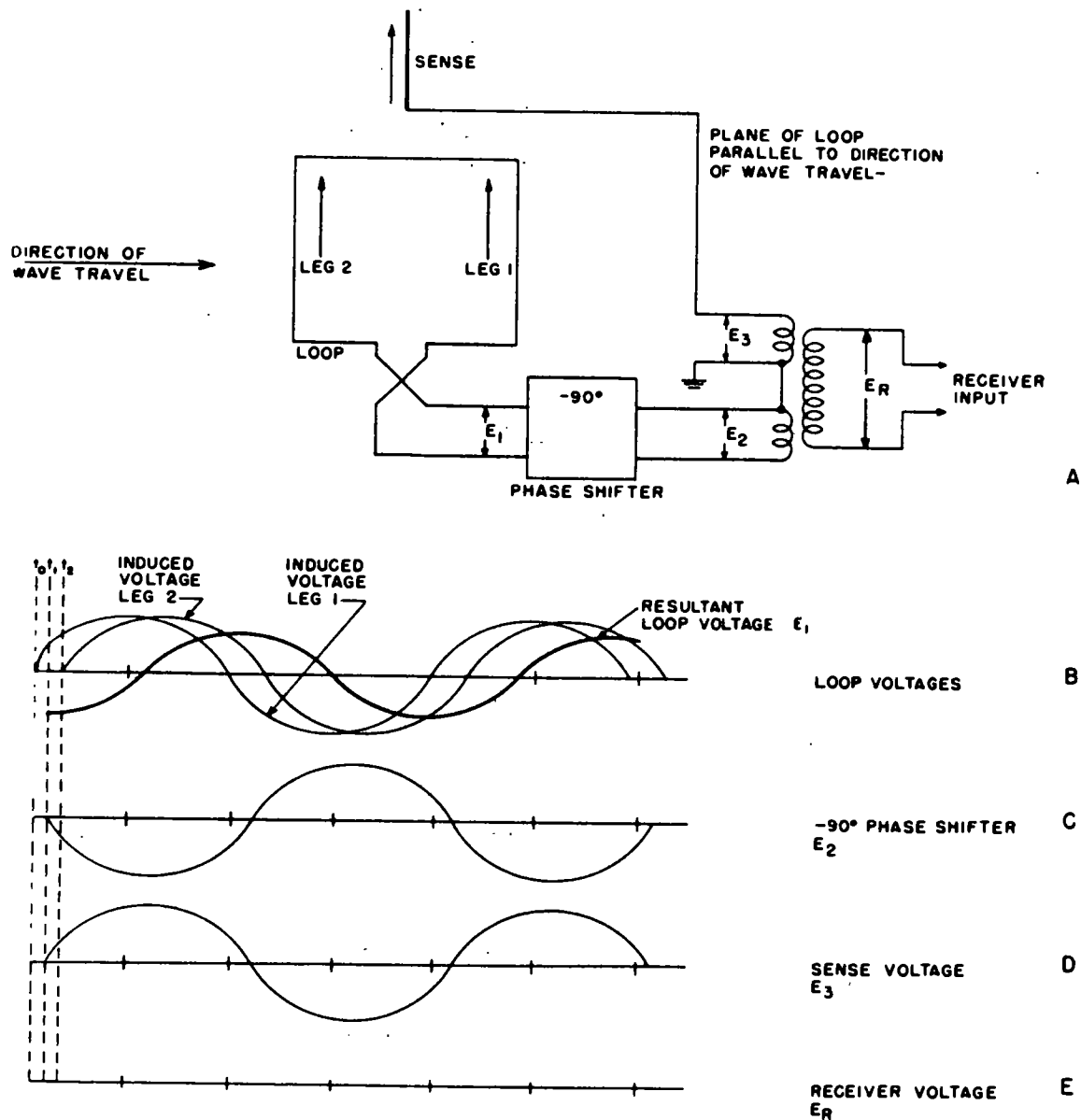


Figure 3-9. Relationship of voltages in loop and sense antenna systems when the loop has been rotated 180 degrees from the position shown in figure 3-8.

b. The voltages induced in the two vertical legs are connected in series opposition, so that the net output of the loop depends on their potential difference.

c. As shown in Capital B, figure 3-8, the voltage in leg No. 1 is starting to rise at time zero (t_0); the voltage induced in leg No. 2 starts to rise a short time later (t_2). However, where the output of the loop is concerned, the voltage induced in leg No. 2 is out of phase and begins to subtract from the voltage in leg No. 1 at this time (t_1).

d. The resultant voltage (E_1) is developed across the output of the loop. This voltage is directly proportional to the time delay (phase shift) between the voltages induced in the legs of the loop. The greater the separation between t_0 and t_2 in Capital B, figure 3-8, the greater the resultant loop voltage.

e. It is apparent in Capital B that the resultant voltage leads the voltage induced in leg No. 1 by approximately 90 degrees and lags the voltage induced in leg No. 2 by the same amount.

f. Voltage E_3 induced in the vertical sense antenna is intermediate in phase between the voltages induced in the two legs of the loops, and therefore lags the resultant loop voltage E_1 by 90 degrees. To compensate for this phase difference (to have either an in-phase or out-of-phase relation between the resultant loop voltage E_1 and the sense voltage E_3), it is necessary to advance or retard the phase of the loop voltage by 90 degrees with a phase shifter. Retarded loop voltage E_2 is shown in Capital C, figure 3-8. If the loop voltage had been advanced, it would be shifted 180 degrees in phase from that shown in Capital C.

g. Notice that the retarded loop voltage E_2 and the sense voltage E_3 , beginning at the same instant (t_1), are in phase. These two voltages add in the input transformer; the receiver voltage E_R is maximum (Capital E, fig. 3-8).

h. If the antenna is rotated on its vertical axis through 180 degrees, the electromagnetic wave strikes leg No. 2 before it strikes leg No. 1 (fig. 3-9).

i. The voltages across both legs are induced in the same manner, producing a resultant voltage again proportional to the separation between the legs. However, because of the loop rotation, the voltages of the two legs are interchanged and the resultant output voltage E_1 is shifted 180 degrees in phase (Capital B, fig. 3-9).

j. The retarded loop voltage E_2 is therefore out of phase with the sense voltage, and the minimum signal E_R is applied to the receiver (Capitals C, D, and E, fig. 3-9).

k. Assume that the transmitter azimuth is 0 degrees as shown in figure 3-10. At

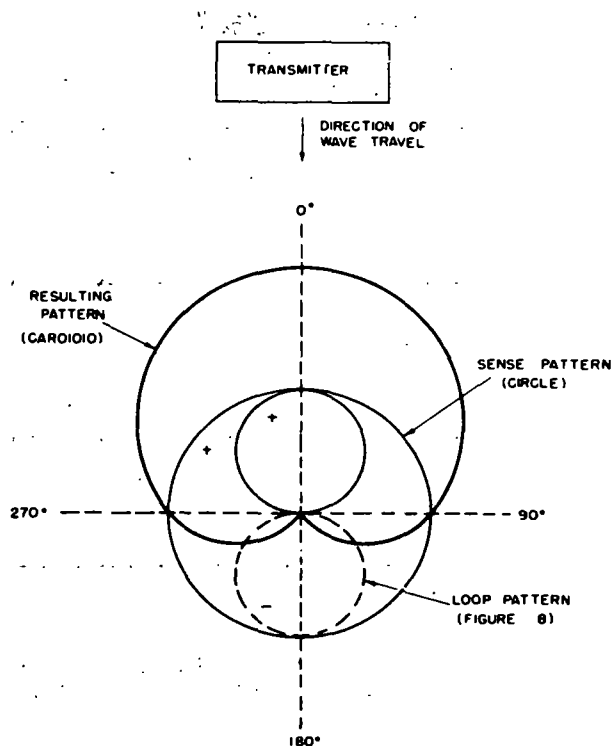


Figure 3-10. Cardioid response pattern.

intermediate points between the maximum and minimum positions of the loop, the following conditions exist:

(1) When the loop is rotated from 0 to 90 degrees, the loop voltage gradually decreases (the distance between the loop legs along the direction of wave travel becomes less). The sense voltage is constant and in phase with the loop voltage. The resultant receiver voltage is decreasing.

(2) When the loop is rotated from 90 to 180 degrees, the loop voltage gradually increases (the distance between the loop legs along the direction of wave travel becomes greater). The sense voltage is constant and 180 degrees out of phase with the loop voltage. The resultant receiver voltage decreases because of the out-of-phase condition.

(3) When the loop is rotated from 180 to 270 degrees, the loop voltage gradually decreases. The sense voltage is constant and 180 degrees out of phase with the loop voltage while the resultant receiver voltage increases.

(4) When the loop is rotated from 270 to 360 degrees, the loop voltage increases. The sense voltage is constant and in phase with the loop voltage while the resultant receiver voltage increases.

1. In practice, sense circuits are seldom adjusted to the ideal condition just described, and the resulting unidirectional pattern is not a perfect cardioid. If the sense voltage is very small, the resultant pattern is a slight lopsided figure eight. Increasing the sense voltage then makes the figure eight more and more lopsided, as shown in figures 3-11 and 3-12, until the sense voltage equals the maximum loop voltage. One lobe then disappears completely, making the pattern a perfect cardioid (fig. 3-13). Further increases of sense voltage increase the maximum and minimum resultant pattern (fig. 3-14), making it more and more like a circle. Either too little or too much sense voltage makes sense determination difficult, while any of the four patterns just mentioned would be acceptable. The

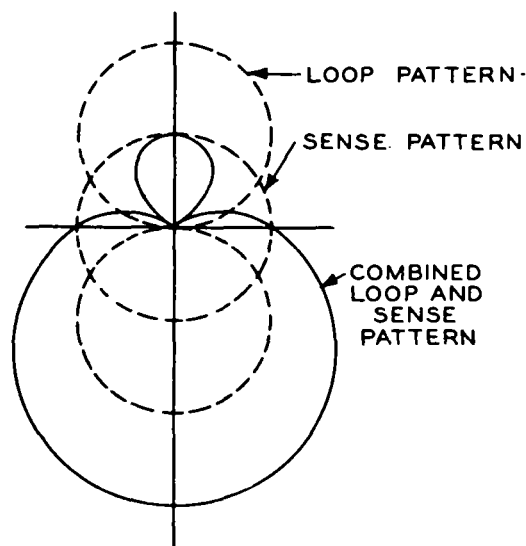


Figure 3-11. Response pattern, low sense voltage, and correct phase position.

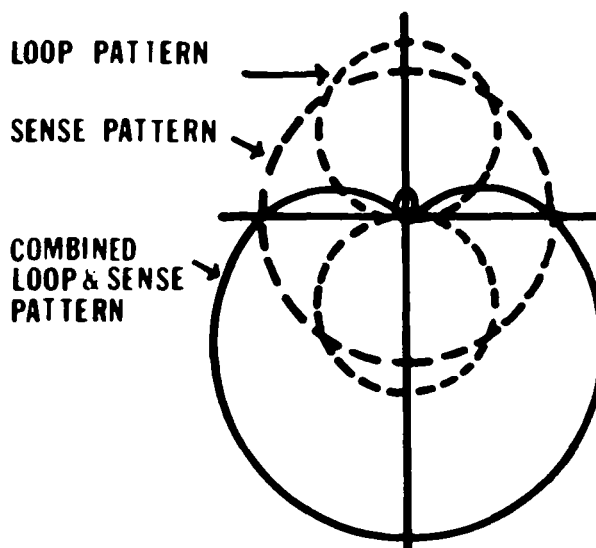


Figure 3-12. Response pattern, low sense voltage, and correct phase relation.

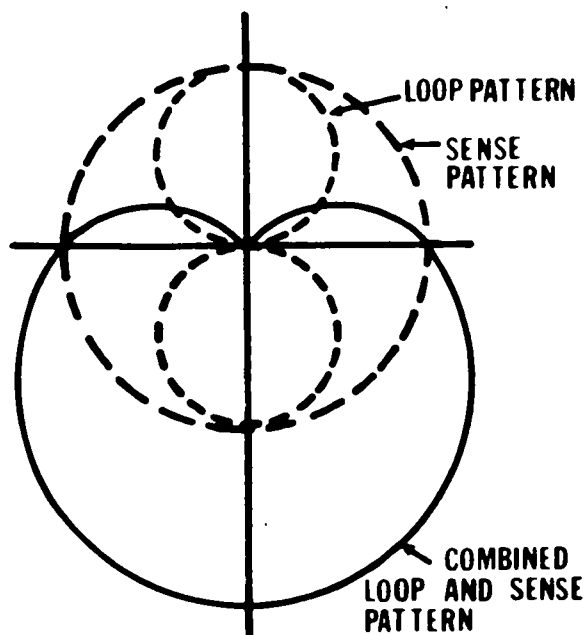


Figure 3-13. Response pattern, proper ratio of sense, and figure-eight voltage with correct phase relation.

lopsidedness of the resultant pattern is readily distinguishable as long as the sense voltage is within ± 50 percent of the maximum loop voltage. If the sense voltage is out of phase with the loop voltage, the resultant pattern becomes nearly circular, and the amplitude relation must be kept closer to the ideal for satisfactory operation. Figure 3-15 shows a case in which both amplitude and phase relation are far from the ideal. Here the sense voltage has about half the amplitude shown in figure 3-11, and is 40 - 50 degrees out of phase with the loop voltage. The lopsidedness of the resulting pattern could be detected by comparing its two maximums on a visual indicator. The difference is too small to be detected by listening. If necessary (for example, if part of the sense antenna is lost), such a pattern can be used by observing which way the null shifts when the sense switch is operated; both nulls shift toward the small end of the lopsided figure-eight pattern.

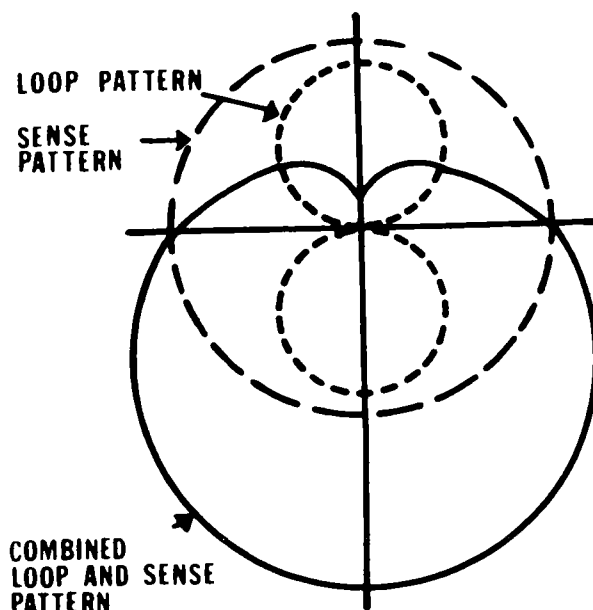


Figure 3-14. Response pattern, high sense voltage, and proper phase relation.

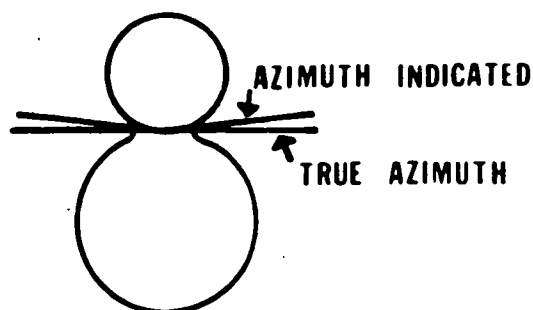


Figure 3-15. Response pattern, low sense voltage, and incorrect phase relation.

3-5. Loop Errors.

Several different factors can lead to undesired effects and incorrect azimuths. Some are peculiar to loops; others can affect any type of directional antenna. Errors arising from causes entirely outside the direction finder will not be discussed in detail here (see sec. III, chap. 5).

a. Antenna Effect. Antenna effect is the error in a loop antenna due to voltage loop imbalance.

(1) *Description.* When combined with the loop voltage, even a weak signal from the sense antenna may cause noticeable distortion of the figure-eight response pattern. If in phase or 180 degrees out of phase with the loop voltage, the sense-antenna voltage tends to make the figure eight lopsided, shifting the two nulls in opposite directions (fig. 3-11) so that they are no longer 180 degrees apart. If 90 degrees out of phase, the sense-antenna voltage tends to fill in the nulls, changing them to rounded minimums. At intermediate phase angles, both rounding and shifting of the nulls occur simultaneously (fig. 3-15). Usually the sense-antenna circuit is designed carefully to prevent any undesired addition to the loop voltage from that source, even though the same antenna effect is still applied to any pattern distortion caused by voltage from the sense antenna.

(2) *Causes.* Antenna effect may occur due to stray pick up. A small amount of signal may be picked up directly by an inadequately shielded receiver, or some circuit not intended as an antenna, e.g., power or telephone wires may pick up a signal and pass it along to the receiver. Probably the most important cause of antenna effect lies in the loop itself. Even when the loop is turned to a null position where the net loop voltage is zero, a relatively strong voltage is induced in each leg, just as in any vertical antenna of the same height. If the loop and associated circuits are properly balanced, this voltage has no

effect on the receiver, while a slight imbalance may combine part of it with the loop voltage in the receiver, producing antenna effect.

(3) *Balance adjustment.* One of the simplest types of imbalance is inequality between the capacitances from each side of the loop to the ground. Such an imbalance can be corrected, as illustrated in Capital A, figure 3-16, by adding a capacitor to each side, making one of them variable so that it can be adjusted for balance. Similar results can be attained with a differential capacitor (Capital B, fig. 3-16). Capacitive balance adjustment can be used even if the imbalance is inductive (unequal inductance in the two sides of the loop), but then a different adjustment is required for each signal frequency, since inductive and capacitive reactances vary in opposing fashion as the frequency changes. A third arrangement, illustrated in Capital C, figure 3-16, uses a differential capacitor to introduce an impulse from the sense antenna. The capacitor is adjusted to make the injected voltage equal and opposite to that entering accidentally. Balancing or neutralizing arrangements are sometimes called null-clearing devices because they are highly effective in eliminating the component of antenna effect which tends to fill in the figure-eight nulls. This component (90 degrees out of phase with loop voltage) is usually the most important. Antenna-effect voltage in the loop is initially 90 degrees out of phase with the desired loop voltage. Loop imbalance couples it into the circuit with little or no phase shift; therefore, the desired and undesired voltages follow the same path and undergo the same phase shifts, retaining their initial relation.

(4) *Shielding and grounding.* Antenna effect originating in the loop itself can be reduced greatly by using an electrostatic shield, as shown in figure 3-3. Similar results can be obtained by grounding the electrical center of the loop. This method is most effective when the loop has an even number of turns so that the center and the

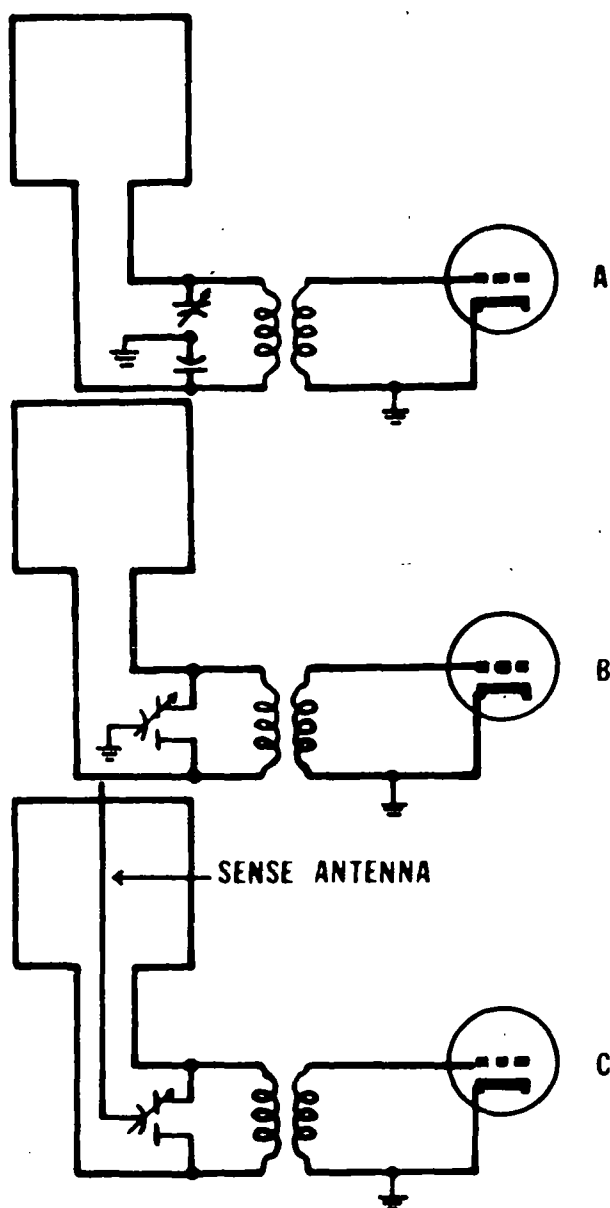


Figure 3-16. Method of balancing antenna effect.

terminals are close together and the ground connection is short. Despite this, it is still quite as effective as a shield. When an input transformer is used in the receiver, grounding the electrical center of the primary coil will reduce antenna effect. However, the electrical

center is more difficult to locate accurately in the coil than it is in the loop. At frequencies far below the natural resonance of the loop or primary coil, grounding and the center tap location need not be extremely accurate. At nearer the natural resonance of the coil frequencies, the tapped coil serves chiefly as an inductive balancing device in a manner similar to the split-stator capacitor in Capital B, figure 3-16. Since its adjustment is fixed by the manufacturer, the center tap must be placed very accurately, and may have to be some distance from the mechanical center of the winding.

(5) *Operating techniques.* Even though technological developments have reduced antenna effect so that it is scarcely noticeable, fairly accurate readings can be obtained from older direction finders in which antenna effect is unpleasantly large.

(a) In cases where the nulls are filled in, the bottom of the resulting minimum cannot be located directly with any great precision, even though the minimum level is definite. By turning the loop back and forth, the operator can locate two points on either side of the minimum where the response rises above the minimum level by the same small amount. The null position is midway between these two points, with a probability error of 10 to 20 percent of their separation, depending on the skill of the operator.

(b) If the two nulls are displaced from their normal 180 degree separation, each null will be in error by an equal but opposite amount (fig. 3-15), called the reciprocal error. This error can be eliminated by averaging the direct azimuths determined from observation of the two nulls. The corresponding direct azimuth is computed from the azimuth at the reciprocal null by adding or subtracting 180 degrees if it is not shown by a separate set of numbers on the azimuth scale.

b. *Weak Signal.*

(1) If the signal is weak or the

background noise is high, several azimuths should be taken when the signal appears strongest. These readings can be averaged to give a reasonably accurate azimuth.

(2) If it is impossible to use the null points, an approximate azimuth can be found by using the maximum points. Direct azimuth, when turned to maximum, is indicated by a signal strength increase when the sense switch is turned on. When the maximum point is used to determine the azimuth, the actual value is 90 degrees less (or more) than the reading of the azimuth indicator.

(3) Often when the noise level is high, the null can be located by averaging the azimuths (up to 90 degrees apart) at which the signal rises above or falls below the noise. Even with low noise levels it is sometimes easiest to locate the null by splitting the arc within which the signal is exceeded by the noise.

c. *Polarization Effects.* As explained in paragraph 3-4c, the response pattern of a loop antenna varies with the polarization of the radio waves received. Abnormal polarization may cause DF errors by rotating the whole pattern or by filling in the nulls, making them difficult to locate. These effects, already observed under several different conditions are:

(1) *Night effect.* When receiving only groundwave signals, a loop is free from polarization effect, both because it has a null in the horizontal direction for horizontally polarized waves, and because any transmitting antenna located near the ground also has a null (or a very small minimum) for horizontally polarized radiation in the horizontal direction. This justifies the assumption that groundwaves are vertically polarized. Skywaves, on the other hand, may have any kind of polarization since they come down at some angle above the horizontal. The loop then responds to the horizontally polarized component as well as to the vertically polarized component of the wave. At the low and medium frequencies used when radio first became popular, the

ionosphere was a much better reflector at night than in the daytime, and skywave reception was possible at night over distances far beyond the groundwave range. Thus polarization error, due to abnormal polarization in the skywave, was first observed at nightfall, and has been called a night effect ever since.

(2) *Fading and swinging.* When both groundwaves and skywaves are received simultaneously with nearly equal intensity, interference results. As the height of the ionosphere fluctuates, the skywaves change phase with respect to the groundwaves, sometimes adding to them, sometimes opposing them. The resultant intensity of the vertically polarized component varies widely, being sometimes much greater and sometimes much less than the horizontally polarized component. As a result, the polarization error varies, and the azimuth indication swings back and forth, making it very difficult to obtain an accurate reading. The amount of swing depends on the relative intensities of the skywaves and groundwaves, reading a maximum of ± 90 degrees if their vertically polarized components cancel each other in the loop.

(3) *Airplane effect.* Polarization error also occurs in direction finding on an airborne transmitter, particularly one using a trailing wire antenna. When the aircraft flies radially to or from the direction finder, vertically polarized radiation is received, and normal results are obtained by DF. When the aircraft follows a tangential course, the received signal has more horizontal than vertical polarization; and the target signal suffers from a polarization error which shifts the indicated azimuth toward the lower end of the trailing wire. Usually this end is to the rear of the aircraft. For courses intermediate between radial and tangential, the ratio of horizontal to vertical polarization is smaller, and so is the error.

d. *Winding Arrangement.* In an unshielded loop antenna, the arrangement of

turns may have an appreciable effect on the directivity pattern. The ideal figure-eight pattern applies exactly to a single turn loop, while more complicated patterns may be obtained when a number of turns are used, unless the turn arrangement is carefully chosen.

(1) *Symmetrical pancake winding.* If the loop turns are wound so that each turn is symmetrical (Capital A, fig. 3-17), the directivity of the loop will be the same as the directivity of any one of the turns. The vertical transition between turns is concentrated in one location with the upgoing and downcoming wires close together. As a result, the voltages induced in these opposing

wires are equal. Complete cancellation takes place, and only those voltages induced in the main portions of the loop affect the receiver.

(2) *Spiral pancake winding.* If the turns are wound spirally (Capital B, fig. 3-17) so that the upgoing side of each turn is longer or shorter than its downcoming side, the pancake loop becomes nonsymmetrical. The inductance and capacitance of the winding are unevenly distributed between the two sides, and this imbalance leads to an antenna effect. The loop circuit can be balanced as shown in figure 3-16, but the relative influence of inductive and capacitive imbalance changes with frequency, so that the compensating capacitor must be readjusted whenever the receiver is tuned to a different frequency. Theoretically, the difference in pick up of a symmetrical and nonsymmetrical pancake, due to the spirality of the latter, is equivalent to the pick up of a small pair of coplanar spaced loops. This tends to make the response pattern slightly sharper at its maximums. (See Capital C, fig. 3-17.) However, this spiral effect is imperceptible in any loop small enough to need more than one turn.

(3) *Skewness.* When a solenoid winding is used for a loop antenna, its form is usually helical, similar to that shown in Capital D, figure 3-17. As the winding progresses, one side of each turn is further advanced than the other by half the spacing between the turns. Thus, the turns are skewed slightly, and their nulls are turned a fraction of a degree from the axis of the helix. A skewed winding is equivalent to two windings without skew (i.e., a primary winding coaxial with the frame, and a smaller secondary winding at right angles with its horizontal part parallel to the axis of the actual helical winding). The secondary loop, figure-eight response pattern (Capital E, fig. 3-17) adds either in-phase or out-of-phase to the primary figure-eight loop voltage. The resultant pattern is also a figure eight, but it has its orientation rotated slightly (much less than that illustrated) from the primary figure-eight pattern.

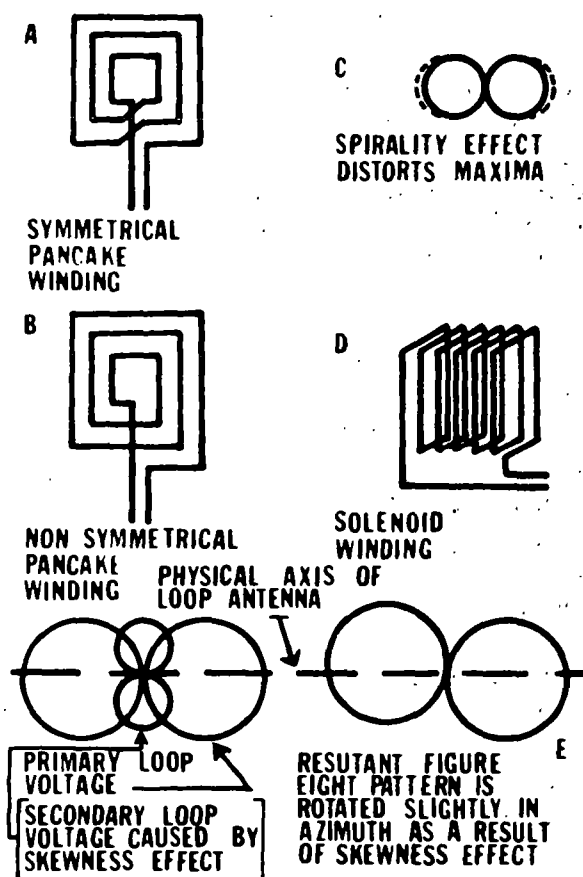


Figure 3-17. Effect of winding arrangement.

(4) *Width effect.* The capacitance between adjacent turns of a solenoid winding produces an effect similar, but with opposite polarity, to that of skewness. As shown in figure 3-18, these capacitances form horizontal members of a secondary loop which is oriented 90 degrees away from the primary loop. The effect of this secondary loop increases with increasing frequency, and becomes large enough to cancel the skewness effect at a frequency slightly below that at which resonance occurs within each turn. If there is leakage between turns due to poor

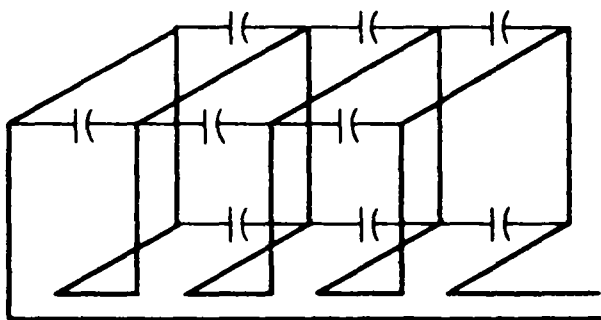


Figure 3-18. Distributed capacities in solenoidal loop.

insulation, the capacitors shown in figure 3-18 may be considered shunted by resistance. This shifts the phase of the secondary loop voltage so that it fills in the nulls of the primary figure-eight pattern rather than rotating the pattern. The result resembles antenna effect. However, because the polarity of the two lobes of the secondary figure eight is opposite, while the circular pattern of actual antenna effect has the same polarity all around, width effect and antenna effect tend to add at one null and cancel at the other so that one becomes slightly more rounded than the other.

(5) *Combination windings.* The peculiarities explained in (2), (3), and (4) above are all attributable to dissymmetry in the loop windings, and can be reduced or eliminated by making the windings more

symmetrical. One symmetrical case is shown in Capital A, figure 3-17. Nearly the same results can be obtained with spiral windings if an even number of pie windings (a method of constructing coils from a number of individual washer-shaped coils called pies) are used, provided that the pies are wound in opposite directions; i.e., spiraling outward and inward alternately. This arrangement keeps the loop balanced and neutralizes the spiraling effect, but still leaves a little width effect. Both skewness and width effect in a solenoid winding can be neutralized by using an even number of layers, one layer being wound from left to right and the next from right to left. Similar results may be obtained with universal windings in which the axial progression of turns is reversed periodically by a cam in the winding machine. Balance still requires an even number of pies which again introduces width effect, which will be insignificant if the number of turns per pie is more than the number of pies. When many turns are used, shielding the loop is often the simplest and most effective solution, since it practically eliminates skewness and width effect. It also reduces antenna effect so that balance becomes less important.

3-6. Loop Construction.

a. *Balance.* The most important factor in the physical construction of a loop is its symmetry. When the loop is symmetrical, electrical balance follows automatically. If the balance is good enough, antenna effect will be insignificant. Any conducting material near the loop, such as the top of the radio receiver case, should be placed symmetrically, otherwise the loop might be balanced at some positions but unbalanced at others. In the case of a square loop, it is preferable to place a corner rather than a side at the bottom. This arrangement keeps the body of the loop farther away from the ground so that any irregularities (including metal items worn by the operator) are less likely to affect the loop balance.

b. Electrostatic Shield. Multiturn loops are often encased in an electrostatic shield. This is a metal case, or a film of metal on a case of some other material, which surrounds the loop winding almost completely (fig. 3-3). There is a gap in the top of the metal, and the opposite sides of the gap are insulated from each other to prevent the shield from forming a closed (short-circuited) loop. The shield is grounded near the loop terminals as far as possible from the insulated gap. As a vertical antenna, therefore, the shield is short-circuited. Consider the voltages induced by a passing radio wave made up of two components, one corresponding to the desired loop voltage, the other to the antenna effect. Although the former can produce very little current in the shield because of the insulated gap, it is fully effective in the loop having conductors crossing that gap. The latter causes a flow of current over the shield to the ground. Since the ground connection is short circuit, this current produces a counterelectromotive force in the shield equal to the original induced voltage. It induces a voltage in each loop conductor which nearly cancels the original antenna effect voltage induced there by the radio wave. The reduction ratio is substantially the same as the Q (reactance/resistance ratio), which the shield would have if connected as a loop. Since the Q is seldom less than 10, the residual antenna effect is seldom more than one-tenth the antenna effect with no shield. In addition to reducing antenna effect directly, the shield helps indirectly. Unless an external object is very close to the gap in the shield, it cannot affect the capacitance from loop to ground, and thus cannot change the capacitive balance of the loop. However, the shield affords no protection against inductive imbalance which might be caused by a scrap of metal placed too close to one side of the loop. The shield also eliminates the precipitation static caused by electrically charged rain drops striking the antenna and provides mechanical protection for the loop.

c. Loop Size. Except in some special VHF loops, which resemble groups of dipoles more than they do ordinary loops, the largest dimension of a loop antenna is usually a small fraction (0.1 at most) of a wavelength. The voltage picked up by such a small loop is proportional to the total area enclosed by its turns; i.e., the product of the number of turns by the average area of each turn. For maximum pick up, the turns should be as large as possible, subject to electrical limitations. Most receivers will not operate efficiently from a loop which is self-resonant at any point within the operating frequency range. Consequently, the number of turns must be small enough to keep the natural resonance higher than the highest operating frequency.

3-7. Crossed-Loop Antenna.

a. General. A crossed-loop antenna consists of two loops with identical characteristics, mounted at a fixed angle of 90 degrees to each other. Each loop has a figure-eight response pattern which is displaced 90 degrees in azimuth. As a result, the ratio of the two responses varies with direction. Several different systems have been devised to make use of this fact.

b. The Goniometer. In the Bellini-Tosi system, the two loops are connected to two stator windings, located 90 degrees apart. In operation a goniometer, whose rotor winding is connected to a radio receiver, is turned to a null or a position of minimum output so that its angle corresponds to the direction of the signal picked up by the loops. Since the loops themselves need not be rotated, they can be made large for the sake of sensitivity. The operation of the goniometer will be explained in detail in section III, chapter 3.

3-8. Adcock Antennas.

a. General. An Adcock antenna consists of two spaced vertical antennas connected in

opposition. Theoretically, it responds only to the vertically polarized component of an incoming radio wave, and therefore is not subject to polarization error. In practice, there is some polarization error due to various imperfections, but usually much less than in a loop antenna receiving the same signal. The Adcock antenna is preferable to a loop in radio DF when medium or high frequency signals must be received at a point beyond groundwave range.

b. Principle. The basic Adcock antenna consists of two vertical elements connected as shown in figure 3-19. The action of such an antenna, as far as vertically polarized waves are concerned, is identical with that of the loop antenna. A resultant current in output coil L is proportional to the vector difference of the voltages induced in the vertical members, exactly as in the case of the loop. Horizontally polarized components of descending skywaves do not affect the antenna because of the absence of the upper and lower horizontal members, and because the crossed arrangement of the center members effectively cancels the voltages induced in them. The response pattern of an Adcock antenna is the same figure-eight pattern typical of the loop antenna. Minimum and maximum response points are present in the Adcock pattern in the same respective positions as in the loop pattern. Thus, the directional properties of the Adcock and loop antennas are the same with respect to vertically polarized waves. The effects of various types of wave polarization on the Adcock circuit are as follows:

(1) *Vertical polarization.* The horizontal magnetic field of the vertically polarized wave cuts the two vertical antenna elements. Induced currents, while they are induced in phase in the vertical elements, oppose each other in the antenna coupling coil, producing a resultant voltage which leads the radiation field by 90 degrees. This resultant voltage is proportional to the

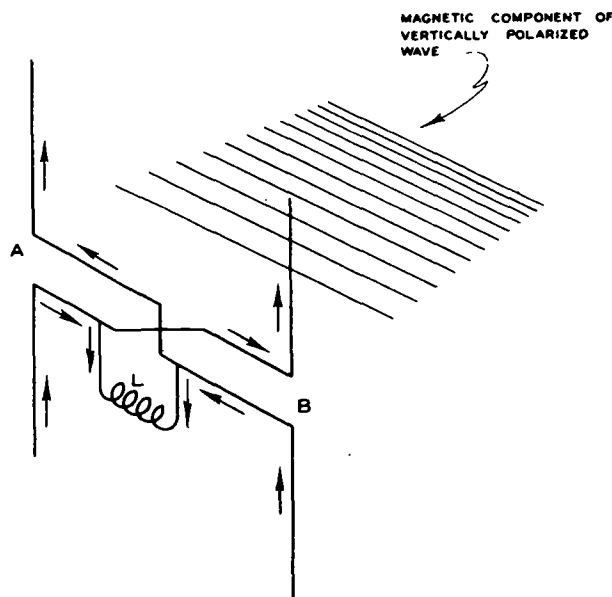


Figure 3-19. Adcock antenna, effects of vertically polarized waves.

separation between the two antenna elements along the direction of wave travel. Thus the action of the Adcock antenna system is identical to the action of the loop system, and can be used in conjunction with a sense antenna to obtain a unidirectional pattern.

(2) *Horizontal polarization.* As shown in figure 3-20, only the horizontal antenna members are in a position to respond to horizontally polarized waves. In a well-designed radio direction-finding system, efficient use is made of shielding and balancing to prevent any voltages induced in the horizontal members from reaching the input stage of the receiver. The residue is small in comparison with the response of a loop under similar circumstances, but it has the same directivity pattern. Thus, the maximum polarization error with an Adcock antenna is still 90 degrees, but is of a lesser magnitude than that of a loop antenna.

(3) *Other abnormal polarizations.* Radio waves usually contain both vertical and

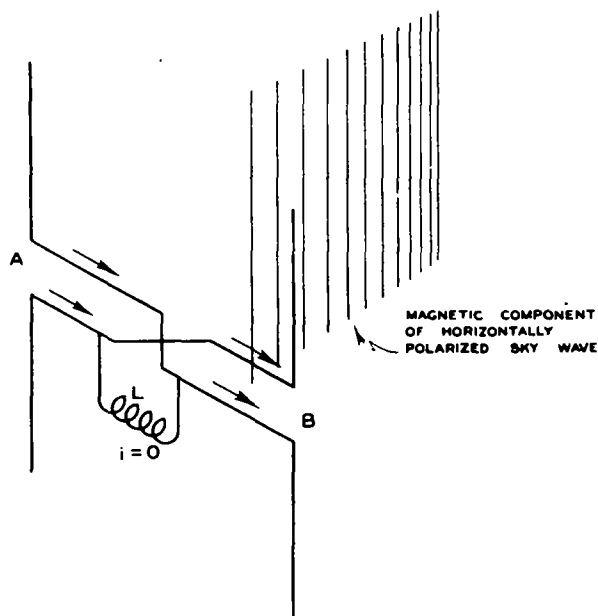


Figure 3-20. Adcock antenna, effects of horizontally polarized waves.

horizontal components of polarization which, in combination, produce an abnormal polarized wave. Although the vertical and horizontal components can be viewed as acting independently, their effect on the antenna is due to the combined action of both components. Because the response of an Adcock antenna is relatively small for the horizontally polarized component, its polarization error is likewise smaller than that of a loop antenna. This is true as long as the vertically polarized component does not entirely disappear. When the vertically polarized component predominates, the Adcock antenna's polarization error is scarcely noticeable.

c. *Types.* All Adcock antennas have the following general characteristics: first, the active antenna elements are vertically spaced wires; second, the horizontal members are arranged so that little or no voltage can be

induced in them; and third, the small voltage that is induced cancels across the output. The various types of Adcock antennas are:

(1) *Simple U-Adcock antenna.* This is the basic type of Adcock antenna (fig. 3-21). U-Adcock antennas are used chiefly in crossed-Adcock systems, which are nonrotatable.

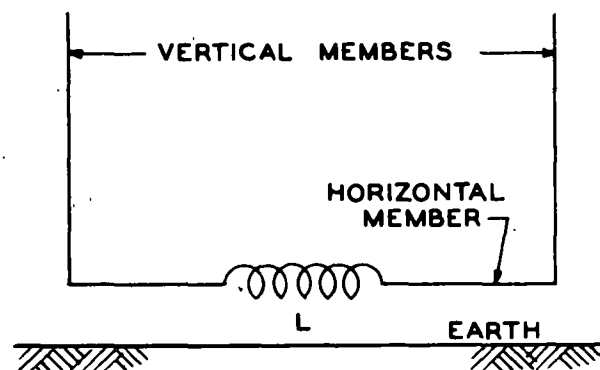


Figure 3-21. Simple U-Adcock antenna.

(2) *Shielded U-Adcock antenna.* The shielded U-Adcock reduces polarization error significantly by shielding the horizontal antenna element. When shielded, its response to horizontally polarized waves is minimized. However, the voltages and currents in the shield set up potentials at the extremities (Capital A, fig. 3-22) which induce voltage into the vertical antenna elements, thus introducing error. Connecting the ends of the shield to metallic plates buried in the ground (Capital B, fig. 3-22) reduces this undesired condition, but introduces another. The shield, ground connections, and earth form an untuned loop which responds to horizontally polarized waves.

(3) *Grounded H-Adcock antenna.* This antenna (fig. 3-23) differs from the others in that its horizontal members are grounded. Directivity, as in the case of the loop antenna, is the result of the differential

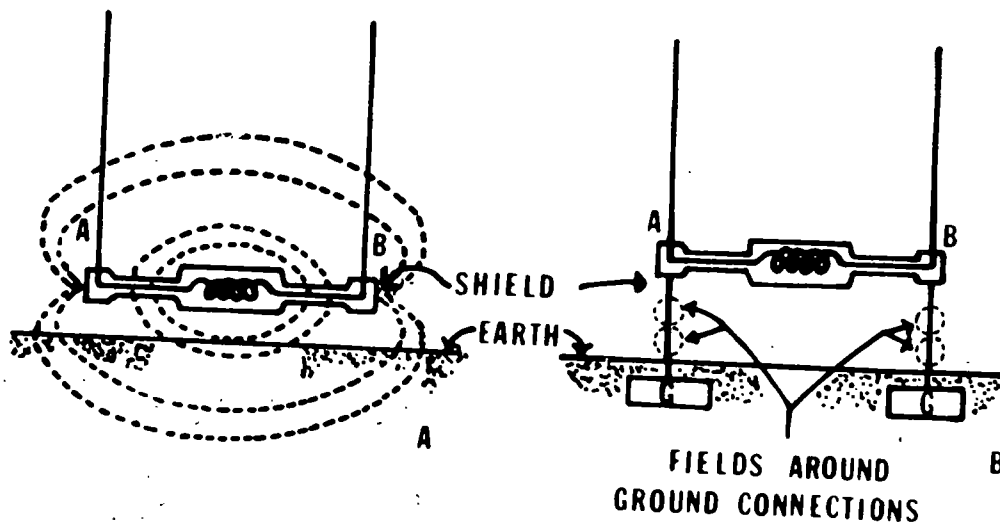


Figure 3-22. Shielded U-Adcock antenna.

action of the voltages in the two vertical antenna elements. The voltages induced in the horizontal antenna elements will cancel. This condition is demonstrated in Capital A, figure 3-23, which shows the distribution of potentials on the horizontal members at a given instant. If equal voltages are induced in all horizontal antenna elements, the resultant voltage across the coil is zero. A problem arises because the lower elements are connected to the ground forming an untuned loop which unbalances the system (Capital B, fig. 3-23). Some of the imbalance can be eliminated by inserting lumped constants in the lower vertical legs (fig. 3-24).

(4) *Elevated H-Adcock antenna.* The elevated H-Adcock minimizes the imbalance caused by grounding the lower portion of the antenna. Balance is obtained through physical symmetry and by raising the antenna a reasonable height above the ground. Depending upon the antenna, balance will be achieved within a fixed height area above the ground. The degree of imbalance increases if the antenna is moved above or below the balance area because of the reduction or

increase in antenna-to-ground capacitance.

(5) *Coupled H-Adcock antenna.* This type of antenna incorporates a highly effective method of reducing the pickup of the horizontal antenna elements and reducing polarization error. Azimuth error is minimized by making the impedance of the horizontal elements high to all currents except those induced in the vertical members. The high impedance is obtained by inserting two mutually coupled impedances in each vertical element (fig. 3-25). This method presents a high series impedance (very small capacitance between windings) to all current directly induced in the horizontal elements; however, a low impedance is presented to the voltages induced in the vertical elements since they are mutually coupled through the transformer and appear directly across the antenna coil. A further reduction in polarization error is obtained by carefully balancing the system of the balanced-coupled Adcock antenna (fig. 3-26).

d. *Tilting Adcock Antenna.* Compared to the loop, the Adcock antenna system is

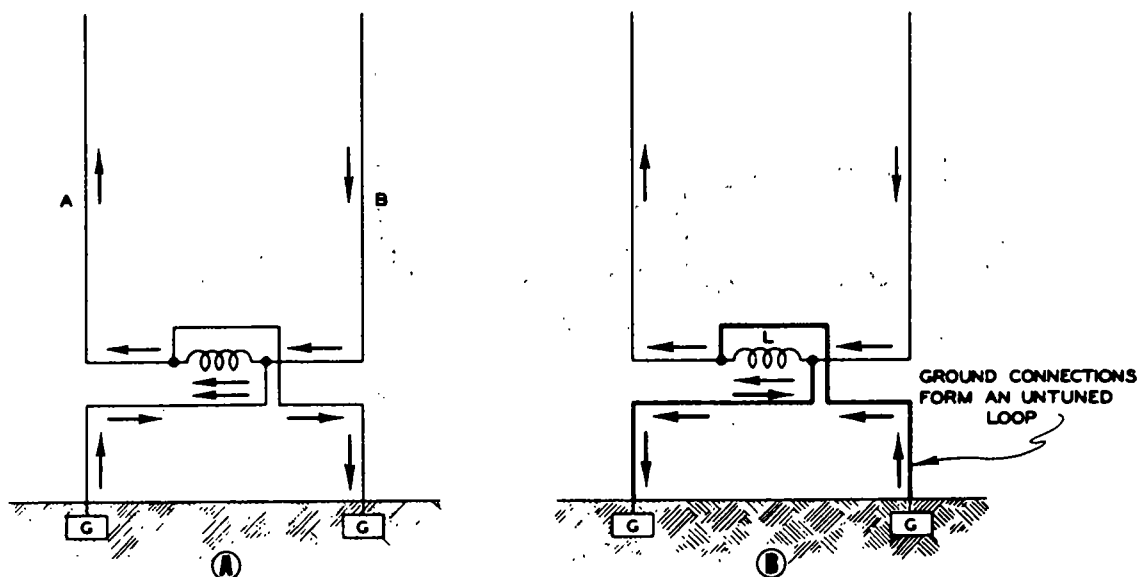


Figure 3-23. Grounded H-Adcock antenna.

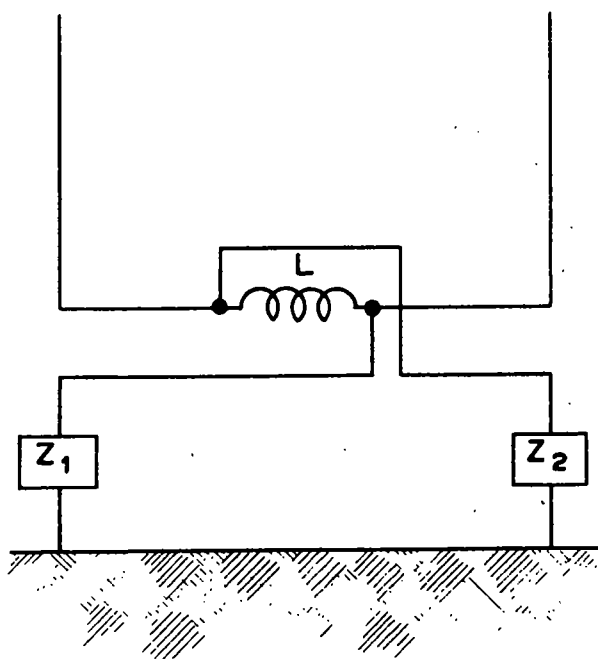


Figure 3-24. Balanced H-Adcock antenna.

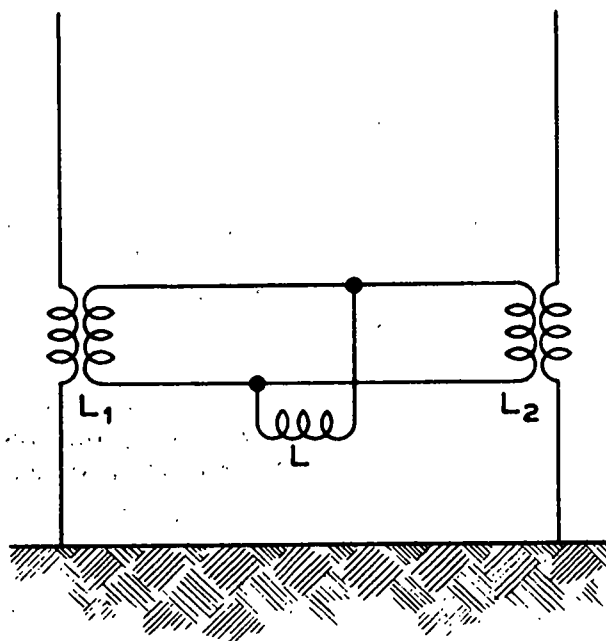


Figure 3-25. Coupled H-Adcock antenna.

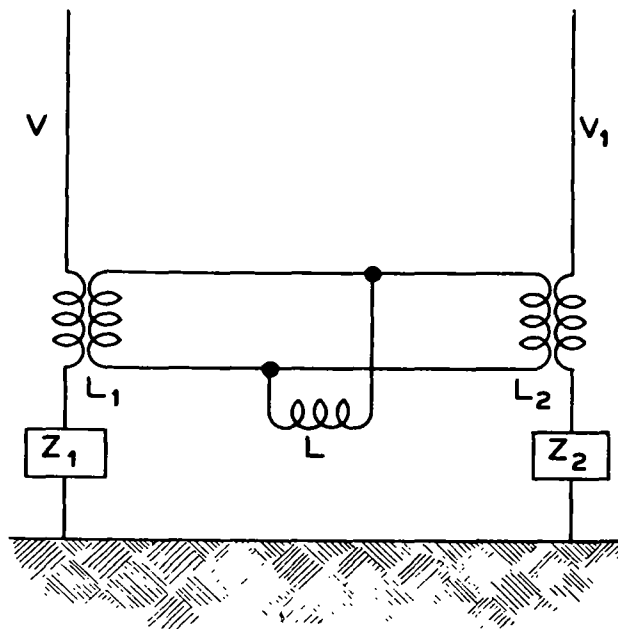


Figure 3-26. *Balanced-coupled Adcock antenna.*

insensitive to high angle radio waves, even if they are vertically polarized. There are two reasons: first, the spacing of the vertical antennas along the path of a radio wave (Capital A, fig. 3-27) grows smaller as the elevation angle increases or the incidence decreases; second, the effective length of each antenna, in the direction of the lines of electric force of the radio wave, is decreased by a similar factor as these lines tilt forward. The effective length reduction can be overcome by tilting the antenna backward, as shown in Capital C, figure 3-27, until it is perpendicular to the direction of the incoming waves, and therefore parallel to the lines of electric force. Tilting improves the system sensitivity when the Adcock antenna is near the direct azimuth. Conversely, sensitivity decreases near the reciprocal azimuth, since the tilt there is the wrong way.

Sense indication also deteriorates because the phase relation between voltages from the Adcock and sense antennas changes unless the sense antenna is also tilted. An Adcock antenna tilted 60 degrees from the vertical might be advantageous for aural-null DF on skywaves from a transmitter 80 to 320 kilometers away, or on signals from a high-flying aircraft 16 to 32 kilometers away, for which the elevation angle may be 45 to 75 degrees.

3-9. Adcock Antenna Errors.

The factors leading to undesired effects and incorrect azimuths when an Adcock antenna is used are similar to those encountered in loop installations. For errors involved in weak signals, antenna effect, and polarization error, see paragraph 3-7. The causes of imbalance (antenna effect) as it applies specifically to Adcock antennas are:

a. The terrain surrounding a radio direction finder is an important factor in obtaining accurate azimuth readings. To obtain the highest degree of accuracy, a DF set should always be operated on level ground, free from neighboring objects such as telephone lines, power lines, buildings, and metallic masses. The presence of such objects or peculiarities in the terrain may cause an imbalanced condition (antenna effect) to exist at the antenna, resulting in possible error. The antenna effect can be reduced by using a stationary Adcock; thus, the relation of the antenna to the ground and nearby objects is fixed, making the final problem of correction less difficult.

b. With a U-Adcock, irregularities in the ground at the base of each monopole may unbalance the system. This effect can be materially reduced with a counterpoise covering the ground between the spaced monopoles and extending beyond them a considerable distance in all directions.

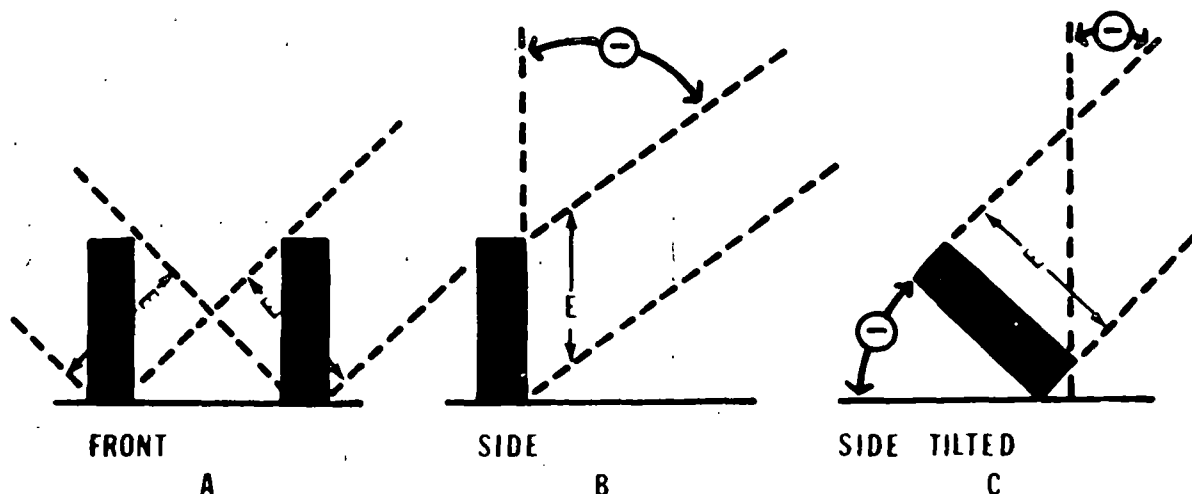


Figure 3-27. Effects of tilting an Adcock antenna.

c. With an elevated H-Adcock antenna, the mere existence of the ground causes a slight imbalance, and any conductors on the ground will make the imbalance worse because the lower ends of the dipoles are naturally closer to the ground than are the top ends. This imbalance leads to polarization error, rather than antenna effect. The difference between the ground is so far away, and the antenna effect resulting from it is rarely, if ever, perceptible.

d. In both types of Adcock systems, shielding of the horizontal transmission lines is useful and sometimes an indispensable guard against imbalance caused by adjacent objects (such as the DF operator). It also eliminates accidental capacitive coupling to other circuits in the vicinity.

e. Another important point in reducing antenna effect is to maintain perfect symmetry and spacing of the antenna elements. Imbalance is caused by having one element slightly larger than the corresponding one, or by having nonuniform spacing. Coupling coils must be identical in inductance and the number of couplings must be equal.

f. Antenna spacing in a rotatable H-Adcock system may be almost a full wavelength before the directional pattern becomes unusable. At spacing exceeding $1/2$ wavelength, the figure-eight pattern has a dimple in the middle of each lobe, which deepens with increasing frequency, becoming a null when the spacing reaches a full wavelength. Even then the antenna still has directional properties, but the extra nulls make interpretation difficult.

3-10. Crossed-Adcock Antennas.

a. *General.* A crossed-Adcock antenna consists of two identical Adcock antennas, oriented 90 degrees apart in azimuth. Crossed-Adcock antennas may be used in various ways similar to those mentioned in paragraph 3-7a. At low and medium frequencies, crossed-Adcock antennas can be made much larger than rotatable Adcock antennas, and are therefore more sensitive. At high frequencies, this advantage is small because of the limitations imposed by spacing effect or octantal error (para 3-19).

b. *Spacing.* In a crossed-Adcock system, the maximum spacing is one-half wavelength between adjacent antennas (0.707 wavelength between diagonally opposite antennas). Above this limit, the same indication may be obtained for signals coming from three different directions (six before sense determination).

3-11. Spaced-Loop Antennas.

a. *General.* The spaced-loop antenna consists of two parallel loops fixed to the ends of a boom which may be rotated about its center or on other "platforms" (various types of aircraft). Earlier models of DF equipment using spaced-loops had the loops mounted perpendicular to the boom, and were said to be coaxial. Since the two loops point in the same direction, the magnitude of the output voltage of each loop will vary in the same manner as the loop is rotated. Besides the normal loop directivity, the spaced-loop system has directivity due to the loop spacing; the latter directivity is not affected by polarization errors. There are two additional types of spaced-loop antenna systems called the vertical coplanar and the horizontal coplanar (fig. 3-28).

b. *Pattern for Vertically Polarized Waves.* The pattern for the coaxial spaced-loop system (Capital A, fig. 3-29) has four nulls spaced 90 degrees apart when vertically polarized waves are received. Two of the nulls occur when the planes of both loops are perpendicular to the direction of wave travel; the other two occur when the planes of both loops are parallel to the direction of wave travel. Although maximum signal is induced in both loops when their planes are parallel to the direction of wave travel, the outputs of both loops are in opposition and cancel across the antenna coupling coil. In this case, the wave strikes both loops at the same instant. If the boom is rotated, less voltage is induced in each loop.

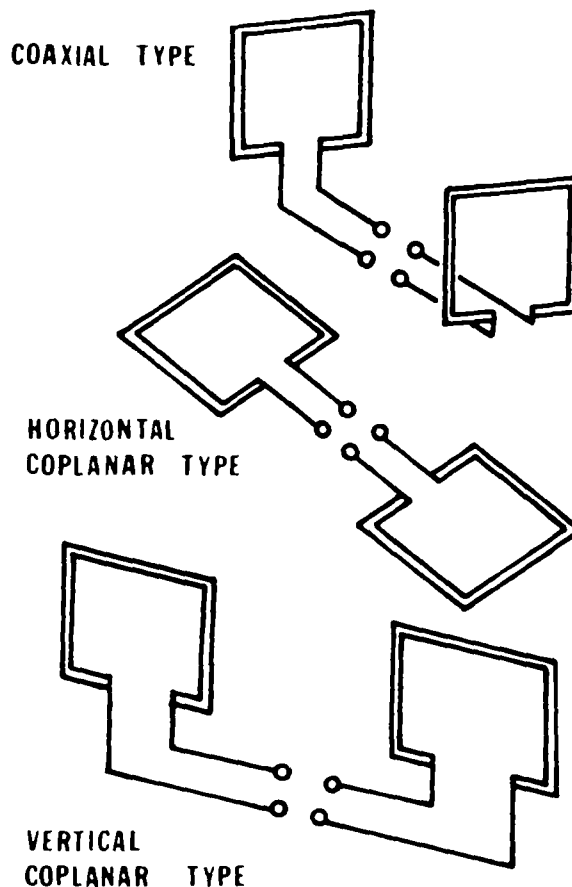


Figure 3-28. Common spaced-loop types.

The wave will strike one loop before it strikes the other, producing a resultant voltage across the antenna coil. If the boom is rotated 90 degrees, the separation between the two loops is maximum. Maximum voltage would be expected to appear in the output, however, this expected result does not occur. When the boom is rotated 90 degrees, each individual loop is perpendicular to the direction of wave travel, and there is no voltage induced in the loops. Therefore, there is a null point every 90 degrees. One set of null points results from the position of the individual loops, the other set from the position of the boom. There is a maximum point located between each

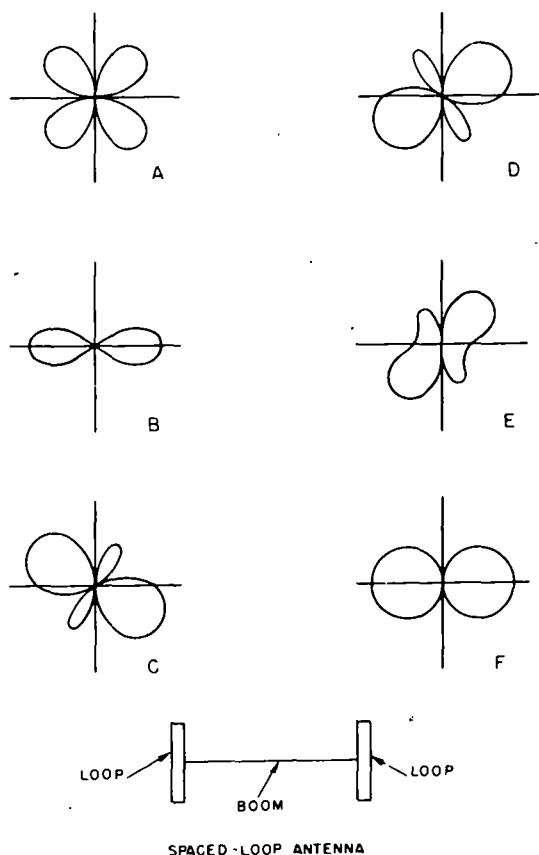


Figure 3-29. Spaced-loop antenna response patterns.

adjacent pair of nulls when both the plane of the loops and the antenna boom are at a 45 degree angle with respect to the null position.

c. Patterns for Abnormally Polarized Waves. Capitals B through F, figure 3-29, show typical response patterns obtained with a spaced-loop antenna (coaxial) when the polarization of the received waves is other than vertical.

(1) Capital B, figure 3-29, closely resembles the response pattern for a wave which is horizontally polarized. This type of polarization is rarely encountered. The pattern is similar to a flattened figure eight.

(2) Capitals C and D, figure 3-29,

show the distortion which occurs when the received waves contain both horizontal and vertical components of polarization. Note that two of the nulls are shifted in azimuth, while the other two nulls remain unaffected.

(3) Capitals E and F, figure 3-29, show typical patterns which may be obtained when receiving elliptically polarized waves (waves containing both horizontal and vertical components which are out of phase with each other).

d. Polarization Error. It is important to note that regardless of the polarization of the received wave, two of the nulls (or minimums) are affected by polarization and shift as the polarization changes. Thus the spacing nulls are free from polarization error, while the loop nulls are subject to it, just as in a single-loop antenna.

e. Taking an Azimuth. The correct null must be used when taking an azimuth with the spaced loop. Receiving a skywave or any other type of abnormally polarized wave, the correct set of nulls appear fixed, while the pair affected by polarization error is indefinite or continually shifting in position. The direct and reciprocal bearings of the correct set of nulls can be determined if the general direction of the transmitter is known, or if a bearing is taken by a loop and sense antenna combination to determine general direction. When the radio wave is vertically polarized and has traveled only a short distance, definite and fixed nulls are found every 90 degrees. The general direction of the transmitter must then be known by other means before the correct null can be selected. When azimuths from several DF sites are plotted on a map, the direct azimuths will intersect near the transmitter location, while reciprocal azimuths and false azimuths (from loop nulls) will either run off the edge of the map without intersection, or intersect at widely scattered points.

3-12. Theory of Doppler Direction Finding.

A signal which is received by a moving antenna will experience a phase modulation in accordance with Doppler's principle. The radiation field has an "equiphase surface" or "wave front" which is equidistant from the transmitter at all points along the wave front. When a receiving antenna is placed in rotational motion about a reference point (fig. 3-30), the signal processed by the receiver will exhibit a sinusoidal phase modulation or frequency change. As the antenna is moved from 0 to 180 degrees, the receiver will experience a frequency decrease because the antenna is moving away from the incoming wave front. When the antenna continues from 180 to 360 degrees, which is toward the incoming wave front, the receiver experiences a frequency increase. No frequency change or phase modulation will be experienced at the direction from which the wave front came nor at the back azimuth (180 degrees opposite). Measurement of this modulated frequency permits the arrival direction of the signal to be determined. This

type of system is used in Airborne Radio Direction Finding (ARDF).

3-13. Quasi-Doppler Direction Finding.

The Quasi-Doppler direction finder locates a wave front or plane and the direction from which it was transmitted is assumed to lie perpendicular to it.

a. Theory. Radio waves travel outward in space from a transmitting antenna at the speed of light and have the same phase at all points which are equidistant from the transmitting antenna. A wave front arriving at two or more distant points simultaneously (Capital A and D, fig. 3-31) is said to be in phase and lie on an imaginary wave front. All points along this wave front are equidistant from the transmitter. Wave fronts in free space are always spherical since all points equidistant from a single point must lie on the surface of a sphere. This point, the center of the imaginary sphere, is the transmitter site.

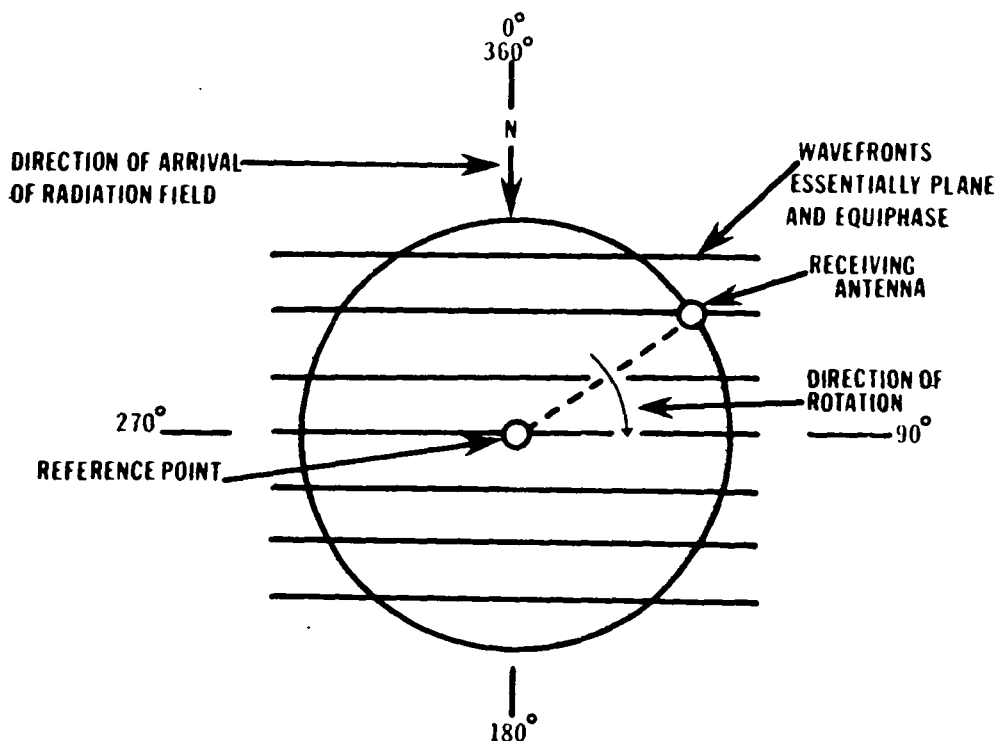


Figure 3-30. Doppler direction finding.

The spherical curvature of the wave front is quite pronounced near the transmitter site, but at greater distances, the curvature is so slight that the wave front may be considered to be a plane surface (Capitals A and D, and E and H, fig. 3-31). A line perpendicular to and bisecting the middle of this plane or wave front between two known points will pass through the transmitter site (Capitals B and C, and E and G, fig. 3-31).

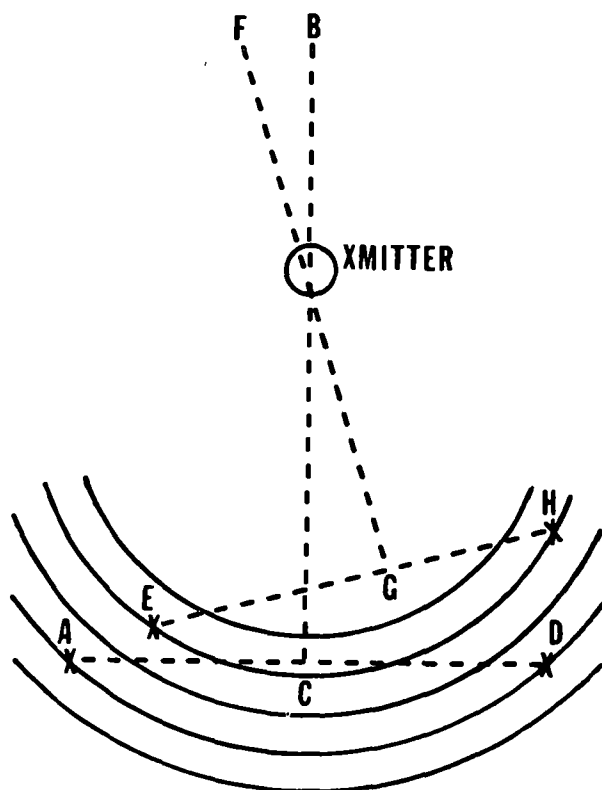


Figure 3-31. Transmitter lies along a line perpendicular to the wave front.

b. Principle of Operation. The Quasi-Doppler direction finder is similar to Doppler direction finding. Instead of physically rotating an antenna through the radiation field, the function is simulated by sampling the outputs of several fixed antennas spaced equally around a circumference equal to that normally traced out by the rotating antenna (fig. 3-32). As long as the number of antennas is sufficient to satisfy the sampling requirement, this system permits the determination of the transmitter's direction by construction of an imaginary plane or wave front (fig. 3-33). The arrival direction of the transmitted signal lies on a line that bisects the middle of, and is perpendicular to, this plane.

Section II TRANSMISSION LINES

3-14. Transmission Lines Used with DF Equipment.

Transmission lines and coupling systems used to tie the actual DF equipment to the antenna system are very closely interrelated. To attempt to separate the information relating to transmission lines and coupling systems would not be in the best interests of this manual. Accordingly, information pertaining to transmission lines will be included in the following section on coupling systems.

Section III COUPLING SYSTEMS FOR DF EQUIPMENT

3-15. General.

a. Coupling systems are defined as those elements of a DF system which serve to couple the directional antenna system to the radio receiver.

b. The coupling system must fulfill the following requirements for satisfactory operation:

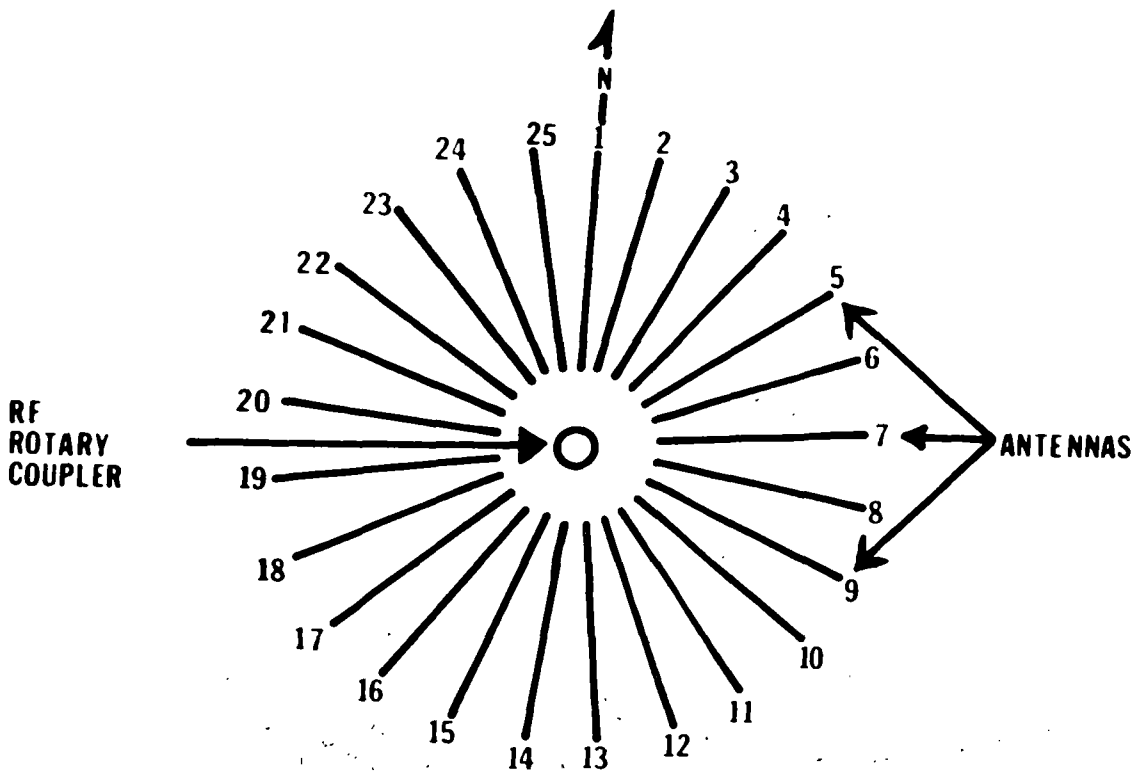


Figure 3-32. Quasi-Doppler direction finder antenna array.

(1) It must efficiently conduct the energy picked up by the antenna system to the radio receiver. If this requirement is not met, the DF will lack sensitivity.

(2) It must not pick up or otherwise introduce additional energy from the wanted signal. Failure to meet this requirement results in bearing errors.

(3) It must not introduce unwanted signals or noise. These effects, if present, produce interference and impair the bearing accuracy.

c. Coupling systems, as used in various types of DF equipment, differ in complexity and type. Common types in general use are discussed individually in two categories:

(1) Systems used with rotatable antennas.

(2) Systems used with fixed antennas.

3-16. Coupling Systems Used with Rotatable Antennas.

a. *Direct Coupling.* Direct coupling, as the name implies, is the simplest form of coupling. The antenna terminals are directly connected to the receiver input. It is used in those few cases where it is practical to design a DF system in which the radio receiver is located at the antenna terminals, and the antenna and receiver rotate together as a unit. Other directly coupled DF sets are small, hand-carried, transistorized receiving sets used by counterinsurgency personnel. The loop is generally the carrying handle, and the entire set is rotated to produce line bearings in the direction of the target transmitter.

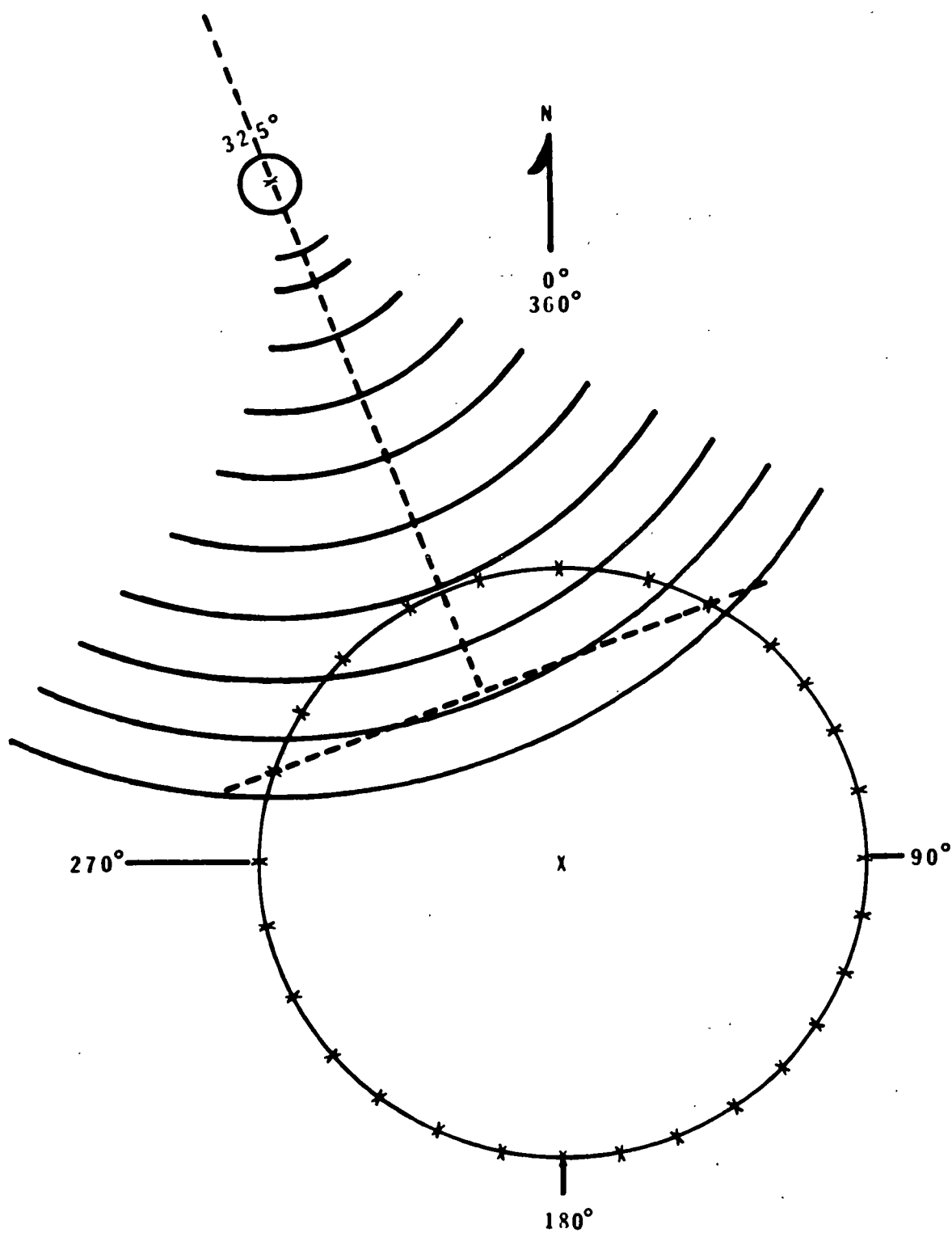


Figure 3-33. Direction finding by a Quasi-Doppler system.

b. Transmission Line Coupling.

Transmission line coupling is used in its simplest form on DF sets in which the antenna system is placed some distance above, but is rotatable with its radio receiver.

(1) Construction of a transmission line coupling system is extremely simple. It is usually made up of a length of balanced, dual-conductor, shielded Radio Frequency (RF) cable, or two balanced lengths of single-conductor, coaxial, shielded cable. However, these place stringent requirements on its design since, by virtue of its length and position, the transmission line will, if its shielding or balance is not perfect, introduce unwanted energy causing bearing errors or impaired readability. In addition, if the length of the transmission line is an appreciable fraction of a wavelength or more, its characteristic impedance must accurately match the impedance of the receiver and the antenna, or a considerable loss of sensitivity will occur. In cases where the transmission line is short, such matching is not essential. However, the series impedance of the line must be small and its leakage impedance great in comparison with the sum of the antenna and receiver input impedances.

(2) The direct and transmission line systems of coupling the antenna to the receiver may be used when it is desired to rotate the antenna without rotating the receiver. This is accomplished by the addition of a rotatable coupling element. Several types of rotatable elements used in various DF sets are:

(a) *Slip rings.* Slip rings are insulated metal rings, in contact with sliding fingers or brushes, which permit rotation without interrupting the circuit. By mounting the rings on a shaft and providing fixed brushes, it is possible to conduct the antenna current to a stationary receiver while permitting the antenna to turn at will. It is customary to make the rings of silver and the brushes of a silver alloy which is either harder or softer than the rings in order to minimize

the variation of contact resistance as the rings are rotated. Such variations give rise to noise which is amplified in the radio receiver and may obscure the wanted signals.

(b) *Rotating transformer.* This rotatable coupling device consists of a transformer whose primary and secondary windings are coaxial. Under this condition, one winding may be rotated with respect to the other without changing the coupling which exists between them. This type of rotatable coupling device can serve as the input transformer of the DF receiver, with the secondary coil turned over a limited frequency range in unison with the rest of the receiver circuits. It can also be used for relatively wide frequency coverage in those cases where its primary and secondary load impedances are substantially uniform and resistive in nature.

(c) *Rotating capacitor.* This form of rotatable coupling element makes use of the fact that the capacitance between coaxial disks or rings is independent of their rotation. This method is customarily used only in VHF equipment since only a small value of capacitance is achievable with elements of reasonable size. At these frequencies, a small capacitance can provide adequate coupling.

3-17. Coupling Systems Used with Fixed Antennas.

In DF, the term goniometer is applied to a device used to couple two or more input circuits (usually connected to antennas) to an output circuit (usually connected to the radio receiver). This is done in such a manner that the degree of coupling varies with the rotation of a shaft. The coupling between one input circuit and the output circuit increases, while the coupling with the other input circuit decreases. When properly connected, a well-constructed goniometer provides an output, at each position of its shaft, identical to that which would be produced by a single

figure-eight pattern antenna oriented to the corresponding position. Thus, the goniometer provides an equivalent for the rotation of an antenna, and makes it possible to use large fixed antenna systems (either loop, Adcock, Circularly Disposed Antenna Arrays (CDAA), or others) which would in themselves be too bulky for an operator to rotate.

a. Inductive Goniometer. The inductive goniometer usually consists of two fixed windings arranged at right angles to each other and inclosing a third winding which is rotatable by means of a shaft (fig. 3-34).

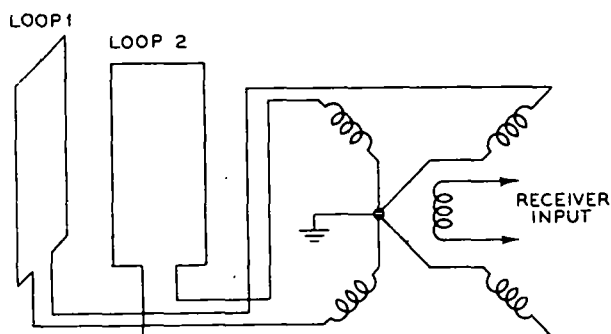


Figure 3-34. Basic goniometer circuit.

(1) When the two fixed windings, arranged at right angles, are connected to identical antennas having figure-eight patterns, the magnetic field within the goniometer will have a direction in relation to the fixed windings corresponding to the direction of arrival of the signal at the fixed antennas. As the internal winding, or search coil, of the goniometer is rotated, its output will vary from maximum to minimum twice per revolution, exactly as would the output of one of the antennas if it were rotated. The positions of minimum output, or nulls, are used to determine the bearing in exactly the same way as if a rotatable antenna was used. The goniometer may be rotated by hand, thus providing manual null-seeking, or it may be continuously rotated by a motor drive and

employed with an automatic visual bearing indicator.

(2) The effect of changing the direction of wave travel on the directional pattern of the goniometer system is shown in figure 3-35. The first column shows the position of the transmitter with respect to the loops, the second and third columns show the position of the goniometer rotor for maximum and minimum signals at each transmitter position, and the fourth column shows the position of the indicator pointer when the DF is set on the correct azimuth.

b. Capacitive Goniometer. The capacitive goniometer consists of two fixed sets of capacitor plates inclosing a rotatable set of plates. Operation of this type is similar to the inductive goniometer except that an electric field rather than a magnetic field is established within the goniometer. In practice, the capacitive goniometer is usually used at frequencies above 100 MHz since it is difficult to construct accurate and efficient inductive goniometers for these frequencies.

c. Requirements. In order to minimize errors, it is necessary to construct goniometers with extreme precision. The basic requirements for accuracy in a goniometer coupling system are:

(1) The fixed elements must be electrically identical.

(2) There must be a complete absence of coupling between the fixed elements.

(3) Accurate positioning of the fixed elements at the same angle as the antennas (usually 90 degrees) is necessary.

(4) Coupling between the rotating element and the fixed elements must vary with shaft revolution in accordance with the same law as the variation of antenna response with azimuth angle. Generally, this means cosine-law variation.

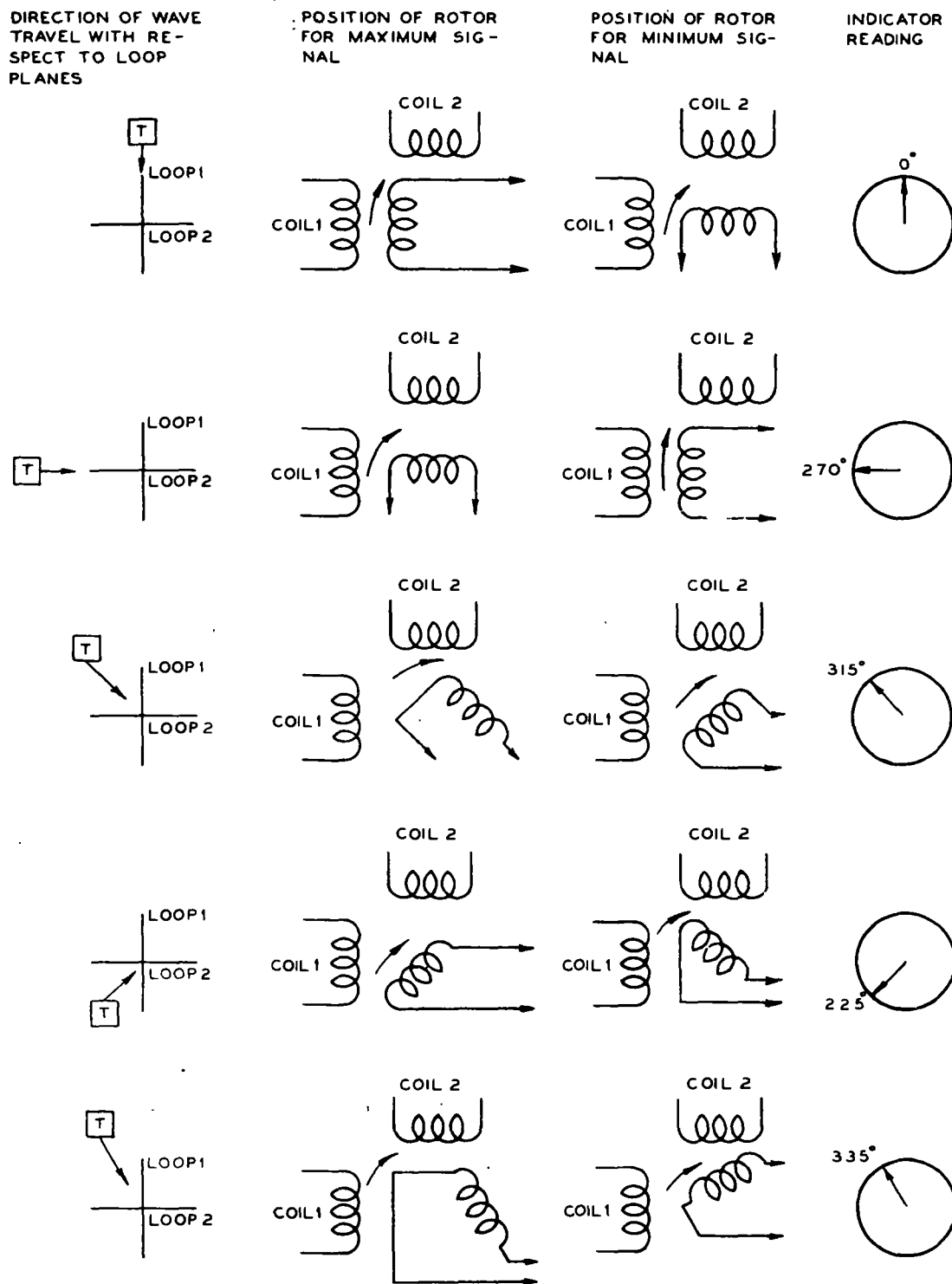


Figure 3-35. Goniometer system, directional characteristics.

Note: These requirements are met in practical goniometers to the extent that the maximum error is less than ± 1 degree.

d. Transmission Lines and Coupling Devices. In applying the goniometer to a practical DF system, it is often desirable to locate the goniometer some distance away from the antenna system. To accomplish this, it is necessary to provide transmission lines between the antenna and the goniometer. These lines must be well shielded and are usually balanced to ground to avoid stray pickup. In addition, the transmission lines connecting the several antennas to the goniometer must be electrically identical, particularly in time delay, over the entire frequency range of the equipment in order to preserve accuracy and provide deep nulls. Such systems customarily use shielded, balanced-type transmission lines laid on the ground. The antennas may be coupled to the transmission lines either through transformers designed to match the impedance of the antenna to the impedance of the transmission line or through amplification type coupling devices. The transmission line length is also critical as varying lengths will cause varied signal strengths to be received. Transmission line coupling must be precise and balanced throughout the system. All couplings must be clean and have maximum contact, if not, signal loss will result. A transmission line with three couplings will have a greater amount of signal loss than a line with two couplings.

3-18. Electronic Goniometer System.

a. This system, in which the varying coupling is provided by means of electronic circuits rather than by mutual inductance or capacitance, is an electronic equivalent of the inductive goniometer. In practice, it is desirable to make the electronic goniometer circuits an integral part of the antenna system. However, the electronic goniometer may be considered as a coupling system applicable to the same forms of antenna

systems as the inductive and capacitive goniometers. The electronic goniometer system is particularly useful with automatic bearing indication systems, since the effective rotation of the antenna system is produced entirely by electronic circuits. This permits the use of high speeds which would be unattainable with a mechanically rotated inductive circuit.

b. The basic unit of the electronic goniometer system is the balanced modulator. This device has two input circuits and one output circuit so arranged that if two different voltages are introduced into the two input circuits, the output voltage is proportional at every instant to the vector produced by these voltages. In the electronic goniometer, the two input voltages are the signal voltages picked up by the antenna and an Audio Frequency (AF) sine wave voltage of a frequency representing the desired rate of effective rotation of the antenna. The output of the balanced modulator, under these conditions, is a modulated envelope comprising the entire spectrum of signals picked up by the antenna. Each signal is completely modulated in amplitude by the audio frequency used. In other words, the output of the balanced modulator contains all the signals picked up by the antenna. However, each signal is varied periodically in amplitude by the AF voltage from its maximum value to zero and back to maximum with reversed polarity, just as if a figure-eight pattern were rotating at the AF rate. Two balanced modulators, upon having their outputs added together, form an electronic equivalent of the spinning inductive goniometer. The outputs of the two balanced modulators combine in such a way that each of the resulting modulated signals reaches its minimum or null at an instant during each AF cycle, corresponding to the direction from which the signal is arriving.

3-19. Octantal Error.

a. In addition to the errors common to the type antenna used, another error, known as octantal error, is introduced by the goniometer. This is caused by the nonuniformity of the flux fields within the stationary windings of the goniometer. In early types of goniometers, this nonuniformity was considerable and, as a result, octantal error was large. In more modern goniometers, however, the turns of both the stator and rotor windings are distributed in such a manner that almost perfect uniformity of the flux fields is obtained. Thus, this type of octantal error is practically eliminated.

b. Octantal errors are also introduced by the physical dimensions of the antenna system as related to the ground. When the spacing of the antenna elements is large with respect to wavelength, the relation between the planes of the antenna elements and the direction of wave arrival does not parallel at all points the relation between the goniometer rotor and the goniometer stationary windings. Instead, the true azimuth is found by adding a correction factor to the azimuth reading. Since the element spacing becomes increasingly longer with respect to wavelength as the frequency is increased, the correction also becomes greater. Generally, an octantal correction chart is supplied with the equipment.

Section IV

BEARING INDICATORS

3-20. Definition and General Characteristics.

a. After energy has been picked up by the antenna, passed through the coupling system, and amplified by the receiver, the bearing indicator translates this energy into an intelligible form from which the operator can determine the direction of the arriving signal. In addition, a bearing indicator may provide information enabling the operator to choose

the most satisfactory moment to read the bearing and to judge the probable accuracy of that bearing.

b. The type of bearing indicator used with any particular DF system depends on the type of DF system in use, the complexity and physical size permitted, and the accuracy desired for a particular DF application.

c. Many types of bearing indicators have been designed and used in DF systems, but those having greatest application can be grouped in the following general categories:

- (1) Aural indicators.
- (2) Instantaneous indicators (scope presentations).
- (3) Automatic bearing-seeking indicators (primarily in airborne application).
- (4) Digital read out.

d. Each type of indicator has certain specific characteristics and applications which are described in detail in this section. Many of these characteristics are closely related to, and cannot be separated from, characteristics of the DF system with which a particular indicator is used. For example, in an instantaneous DF system, many of the features exhibited by the indicator are not necessarily characteristic of the indicator alone, but are the combined characteristics of the antenna, coupling, and indicator system.

3-21. Aural Null.

An aural null is the decreased audio tone of the received signal when the antenna is at right angles to the arriving wave front and the signal components (phase relationship and signal strength) are identical. Electronically, when signals of equal value are "beat" (mixed together), these signals will, among other effects, cancel each other. This cancellation results in the decreased audio tone.

a. *Aural Indicator.* An aural indicator is a headset or loudspeaker connected to the DF

receiver audio circuit. It enables the operator to detect the signal bearing by changes in the audible receiver output as the antenna is rotated. In DF systems using aural indicators, the antenna system must be rotated to the bearing position. This position must be characterized by an abrupt change in the antenna response pattern and, therefore, in the receiver output.

b. Types. In the most common DF sets using aural indicators, the antenna is a rotatable loop or Adcock, or a fixed crossed-loop or crossed-Adcock effectively rotated by a goniometer. All these antennas have, or result in, a figure-eight response pattern with broad maximums and sharp nulls. Therefore, the nulls of the antennas are selected as the bearing points. Aural indicators used with DF sets having these types of antennas are commonly called aural-null indicators. At the higher frequencies (several hundred megahertz), directional arrays having response patterns with sharp maximums can be used. Aural indicators operating with these antennas might be called aural-maximum indicators. The remainder of this paragraph is limited to a discussion of aural-null indicators rather than aural-maximum indicators because they are the most common in DF equipment currently deployed.

c. Characteristics. The important characteristics of the aural-null indicator are as follows:

(1) It is the simplest indicator that can be used with a DF set since:

(a) It adds nothing to the DF because a headset or speaker is usually included for monitoring purposes.

(b) It can be used with simple-loop or Adcock antenna systems without the addition of complicated coupling systems.

(c) It reduces to a minimum the size, weight, and maintenance factors of the indicator.

(2) The indicator cannot detract from the accuracy of the remainder of the system.

(3) The readability of the indicator is not influenced by the type of signal received, whether it is Continuous Wave (CW), Interrupted Continuous Wave (ICW), or Modulated Continuous Wave (MCW).

(4) The readability of the indicator is high on weak signals in the presence of noise or interfering signals because the human ear can differentiate between desired and undesired signals.

(5) The readability of the indicator is poor on fading signals because it cannot discriminate between a fade and a null indication.

(6) An extra operation must be performed to determine sense.

3-22. Visual Bearing Indicator Systems.

More sophisticated equipment is required for systems providing visual bearing presentations. A meter or oscilloscope must be used to determine the bearing direction. Most DF equipment currently deployed has a scope integral to the circuitry. On the scope face, the signal bearing is displayed in a number of forms or shapes.

a. Instantaneous (Oscilloscope) Indicators. An instantaneous visual indicator using a Cathode-Ray Tube (CRT) continuously and automatically presents a pattern or trace on the tube screen that points toward the azimuth of the arriving signal or an azimuth scale around the face of the tube (fig. 3-36). The presentation of this pattern or trace is accomplished without manually rotating the DF antenna to the bearing position.

b. Application. The application of an instantaneous indicating device to a DF system is possible only if the antenna system is one of the following types:

(1) A fixed, oriented, crossed-loop, or crossed-Adcock variety that may be effectively rotated 360 degrees at a constant rate by a spinning mechanical or electronic goniometer.

(2) A fixed, oriented, crossed-loop, or crossed-Adcock variety, the outputs of each of the crossed-loop or Adcock antennas

maintained as separate signals through a dual-channel receiver, or through a system of antenna switching and a single-channel receiver, to individual channels in the indicator.

(3) A single-loop or Adcock that is continuously rotated 360 degrees by mechanical means at some constant rate.

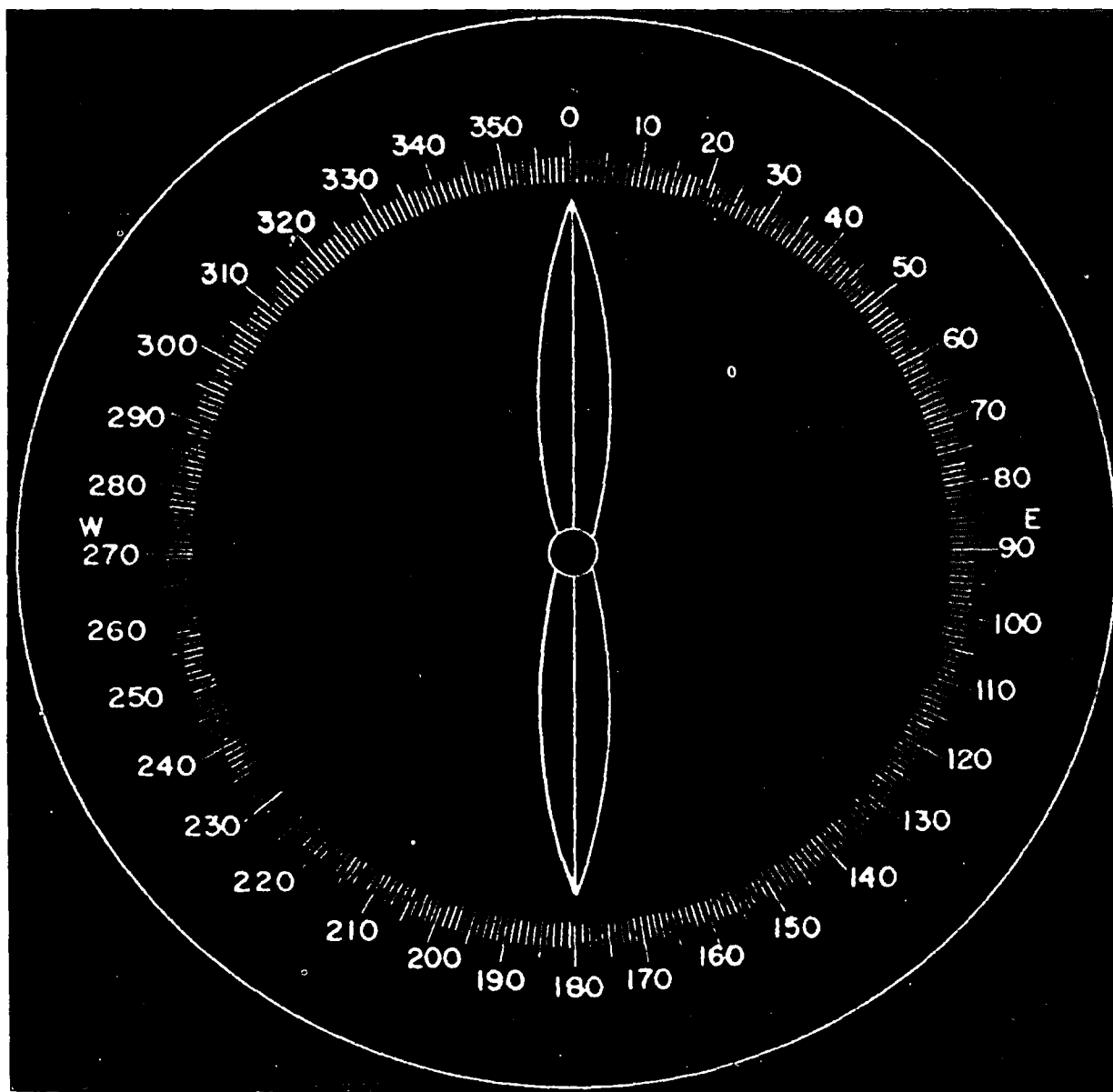


Figure 3-36. Typical position of azimuth scale on instantaneous indicator (oscilloscope).

(4) A Circular Disposed Antenna Array (CDAA) equipped with monitor beams, power combiners, and much greater sophistication than has thus far been discussed.

(5) Inverse LORAN.

(6) Single Site Position Assembly Location.

c. Characteristics. Because these special features must be incorporated in a DF system using an instantaneous indicator, its size, weight, power consumption, complexity of design, and maintenance are greater than in systems using aural-null indicators. When not prohibitive, these disadvantages are more than compensated for by the increased performance obtained when using this type of indicator. Characteristics of instantaneous indicators in comparison with similar characteristics of aural-null indicators are as follows:

(1) There is greater speed in obtaining bearings because the antenna is not manually rotated to the bearing position. Bearings can be taken as quickly as the receiver can be turned to the desired signal and the bearing read directly from the indicator. In autotune systems the productivity of a remoted DF site is greatly increased.

(2) Simplicity of operation is increased. Tuning the receiver and reading the bearing are the only operations necessary. Alinement and balancing procedures, although not difficult, must be carefully accomplished by experienced operators or maintenance personnel as appropriate.

(3) Readability is increased. Although its readability on strong signals is not appreciably greater than the aural-null system previously discussed, its readability on moderate and weak signals is considerably greater.

(4) There is equal readability on CW, ICW, and MCW signals.

(5) Readability on swinging signals is increased because the indication

continuously and instantaneously changes with the bearing swing, and thus permits the operator to choose the bearing that most likely is correct.

(6) Readability on fading signals is increased because the indicator has a high degree of discrimination between a change in signal level, due to fade, and a change in bearing.

(7) There is increased readability on combinations of swinging, fading, and unfavorably polarized signals, because the indicator exhibits certain features which tell the operator when conditions are most favorable for obtaining a bearing.

(8) Readability in the presence of interfering signals is fair, although not as good as aural indicators. This reverts back to the discrimination by the ear between two signals with only fractional frequency separation. Auto tune systems however, have largely eliminated adjacent channel interference by remotely tuning the DF receiver to within 25 Hz of the target frequency.

3-23. Bearing-Seeking Type Indicators.

a. A bearing-seeking type indicator is used with those DF sets in which the antenna system is automatically rotated by an electric motor to the true bearing position of the source of signal to which the DF receiver is tuned. The bearing indicator in such a system is the component which controls the rotation of the loop driving motor. It causes an indicating pointer to revolve and come to rest when pointing at the azimuth of a signal as read from a circular azimuth scale. The rotation of the antenna is quite often electronic instead of manual. The bearing presentation, however, is still as described above. This type indicator is used primarily in airborne applications and is identified as Automatic Direction Finding (ADF), or automatic radio compass. This information is included to ensure an overall understanding of DF. The ADF provides the pilot with a continuous and automatic indication of the

azimuth to the transmitter. In reality, the automatic radio compass is a left-right, loop-type DF with a servosystem (or electronic system) which automatically (or electronically) turns the loop to its true null.

b. The output of a left-right DF when the loop is off bearing is an audio signal at the loop switching frequency whose amplitude and phase are a function of the loop position with respect to the loop null. In an automatic radio compass, the variations in phase and amplitude of the receiver output voltage cause the loop to be driven by a reversible electric motor (or electronic switching system) to a point of null or zero pickup.

c. The widest application of a bearing-seeking type indicator is in homing type DF for aircraft where size and weight requirements do not permit the use of instantaneous indicators, but where an automatic DF (in the sense that operator/pilot does not have to rotate the antenna to the bearing position and the true bearing is continuously indicated) is required.

d. Characteristics of bearing-seeking type indicators are as follows:

(1) It has simplicity of operation comparable to that of instantaneous indicators. The only operational requirement is tuning the receiver to the desired signal and reading the bearing on the indicator.

(2) Readability on strong and moderate CW, ICW, and MCW signals is as good as that of indicators previously discussed.

(3) Readability on weak signals, swinging and fading signals, and on signals in the presence of adjacent channel interference is not comparable to the readability of instantaneous indicators.

(4) Automatic sense indication is coincidental with bearing indication.

Section V

DF RECEIVERS

3-24. DF Receivers.

Any good quality receiver that has excellent sensitivity and selectivity, and can be modified for compatibility with necessary auxiliary equipment, can be used as a DF receiver.

CHAPTER 4

Types of Direction-Finding Efforts

Section I

TERMINOLOGY ASSOCIATED WITH DF EFFORTS

4-1. General.

a. Directwave Direction Finding. Directwave Direction Finding (DWDF) is the term used to identify the DF effort against transmitters located close enough to the DF site that the direct component of the transmitted wave is used to locate the transmitter.

b. Skywave Direction Finding. Skywave Direction Finding (SWDF) is the term used to identify the DF effort against transmitters whose location is far enough away from the DF site that their radio waves have been reflected or refracted by the atmosphere prior to their interception by the DF site.

c. Airborne Radio Direction Finding. Airborne Radio Direction Finding (ARDF) is the term used to identify the DF effort conducted from an airborne platform.

Section II

DIRECTWAVE DIRECTION FINDING

4-2. DWDF Factors.

Radio wave propagation is an extremely important factor in all types of DF. Although a review of wave propagation was given in chapter 2, it is necessary to describe some important differences between wave behavior in the MF/HF frequency range and those in

the VHF/UHF range, since these effects have important operational effects on DWDF activities.

a. In the VHF/UHF frequency range (30 MHz and above):

(1) Communications are predominantly short range and line-of-sight.

(2) FM voice is the primary type of transmission.

(3) Transmitters are usually highly mobile, either manpacked or vehicle mounted. They commonly use whip antennas which are nondirectional and vertically polarized.

(4) Transmission is mostly by means of the direct component of the groundwave. Wave travel is primarily in a direct path from the transmitting antenna to the receiving or DF antenna (fig. 4-1).

(5) The directwave component is generally not greatly affected by the ground over which it travels. It is, however, subject to reflection and reradiation by objects above the ground in its wavepath (fig. 4-2).

b. At this point, it is necessary to discuss how reradiation affects the DF effort. Reradiation occurs when the wave front encounters an object composed of any material having high electrical conductivity, is of a size that approximates the wavelength (including fractions or multiples thereof), and has the same polarization. For example, an FM radio transmitting on a frequency of 50 MHz using a quarter-wave vertical whip antenna is located at point A in figure 4-3. The hill mass between the transmitter at A and the DF sets at B and C would ordinarily make it impossible for the transmitter to be heard at the DF sites. A metal fence post approximately 1.5 meters in height is located at point D. As the wave transmitted from the

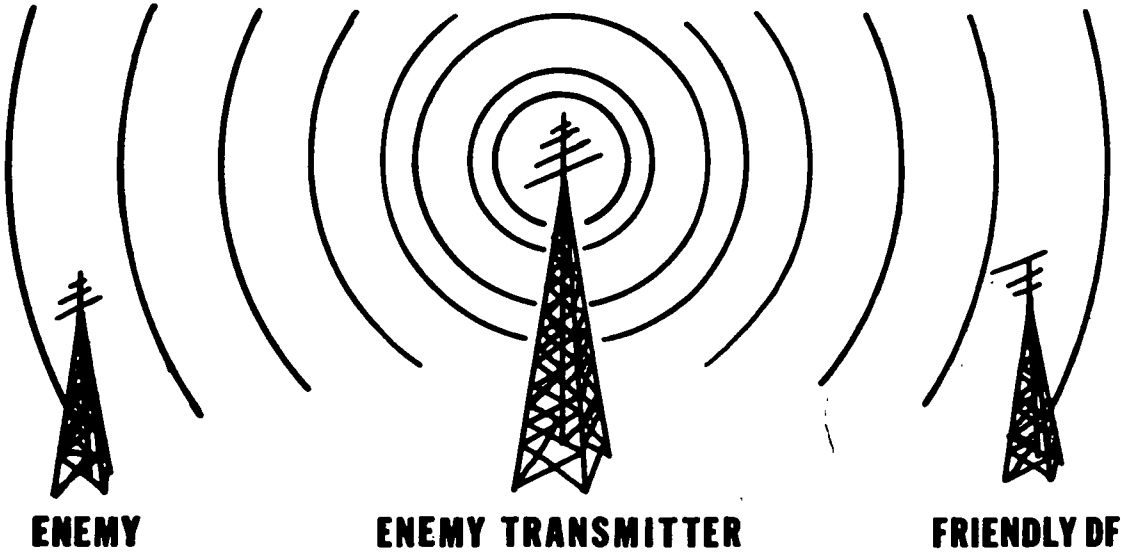


Figure 4-1. Direct wavepath.

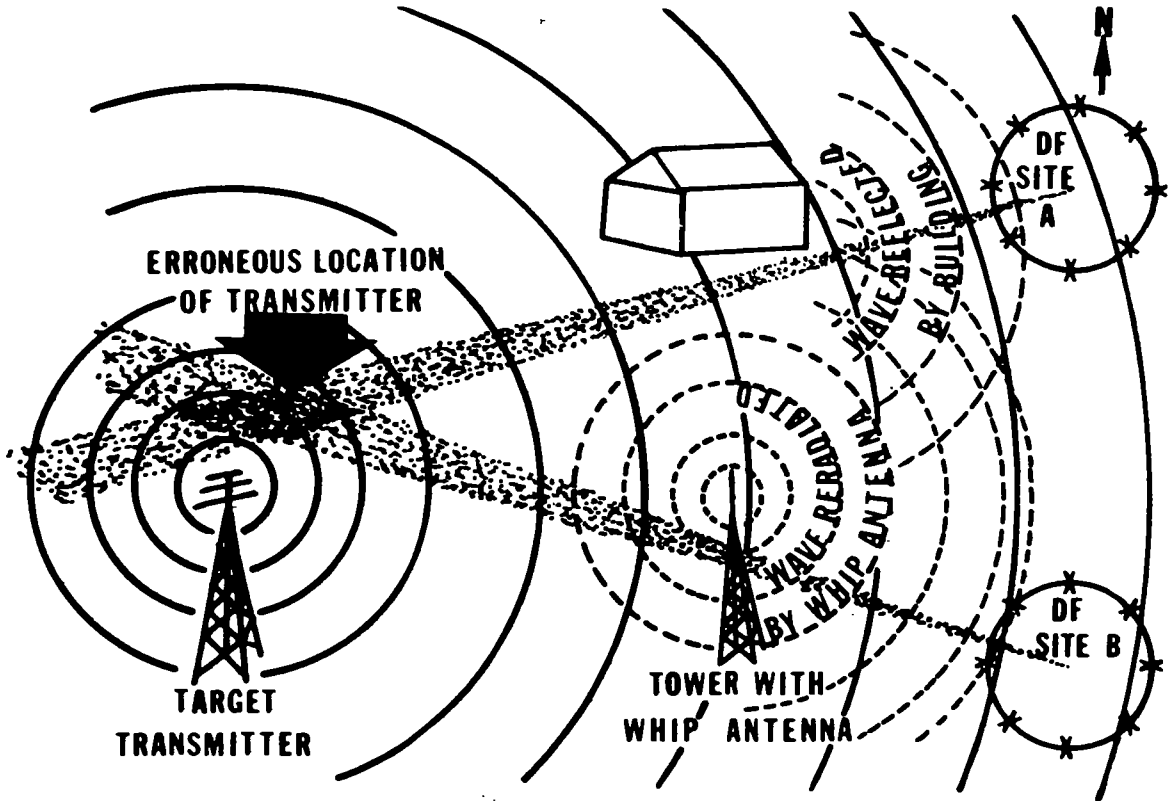


Figure 4-2. Wave reflection and reradiation.

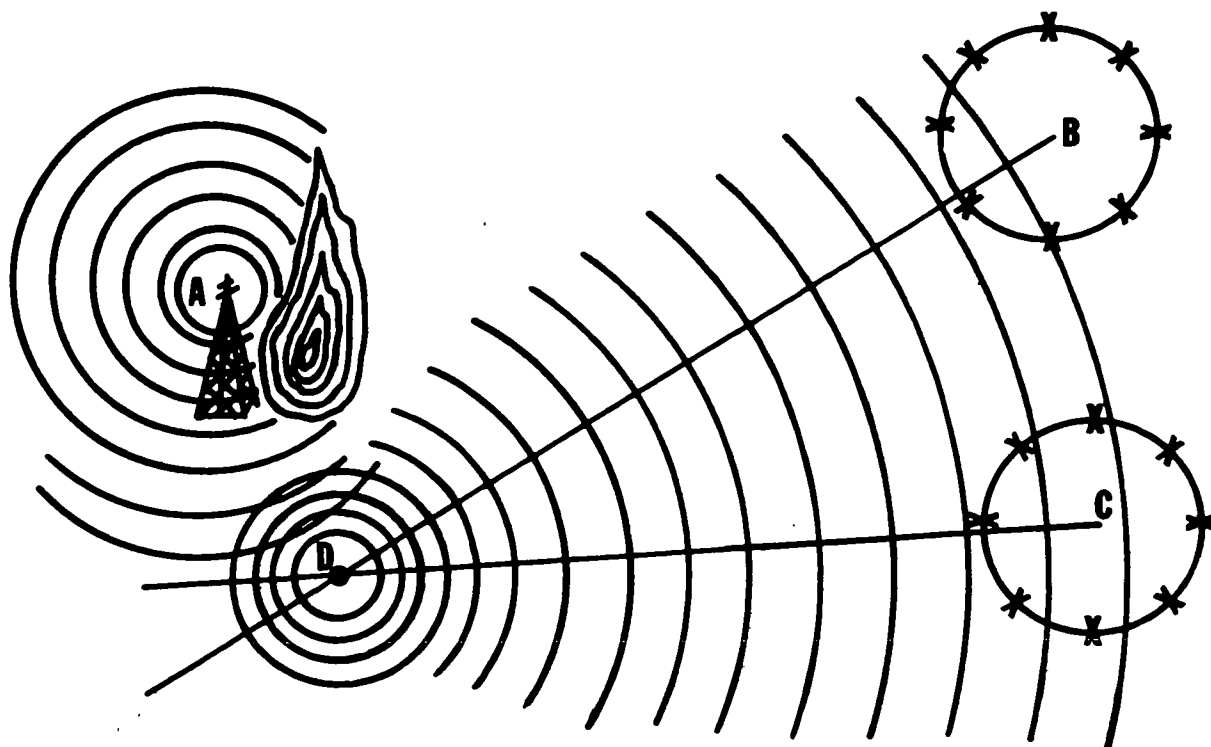


Figure 4-3. Reradiation of transmitted signal.

FM radio passes by the fence post, a small induction field is built up around the post. Since the 1.5 meter post is a quarter-wavelength of the radiated wave, a resonant radiation field is set up causing the wave to be reradiated from the fence post. In this instance, the DF sites will indicate an erroneous location for the transmitter. The reradiated wave is much weaker than the original wave, but when a directwave and a reradiated wave are present at the same time, as shown in figure 4-2, the weaker reradiated wave may still be of sufficient intensity to affect the accuracy of the DF bearing.

c. The discussion pertaining to wave propagation indicates that groundwaves are composed of several components. The waves

radiated from a transmitting antenna spread out into the atmosphere and along the earth, as well as into the earth. Because of the conducting properties of the earth, some of the energy is reflected from the earth's surface. The part of the wave not reflected enters the earth where the energy rapidly dissipates as heat. Other portions of the waves spread out along the earth and into the atmosphere and travel to the receiver, providing radio communications, and to the DF set. The field intensity of the groundwave and the range over which groundwave communications can be conducted depends upon many factors (see section III, chapter 2). Most of the received groundwave field intensity can usually be accounted for in terms of one or more of the factors discussed

previously. The resulting groundwave is, therefore, composed of one or more of the following wave components: direct, ground reflected, surface, and tropospheric.

(1) *Directwave.* This component travels directly from the transmitting antenna to the receiving antenna. The directwave is not appreciably affected by the earth's surface, but is subject to refraction in the atmosphere between the transmitter and the receiver. This refraction is particularly important in the UHF range. The directwave is the principal means of transmission in tactical VHF communications circuits, and therefore is of prime importance in DWDF operations above 30 MHz. The directwave (along with the ground-reflected wave) is also the most important wave component in Airborne Radio Direction Finding (ARDF) at all frequencies.

(2) *Ground-reflected wave.* This component reaches the receiver after being reflected off the ground.

(a) If both the transmitter and receiver (or DF set) are located on the ground, the difference in path lengths between the direct and the ground-reflected waves is small. These waves arrive almost exactly 180 degrees out of phase, resulting in almost complete cancellation. This is particularly true at frequencies below 30 MHz due to the relatively long wavelengths. The difference in path lengths between the direct and ground-reflected waves would have to be relatively large to compensate for the 180 degree phase shift at the point of reflection. Therefore, in this instance, DF of groundwave communications below 30 MHz are conducted primarily with the surfacewave component.

(b) As the height above the ground of the receiver antenna increases, the difference in the path lengths of the two components increases until a point is reached where the difference is equal to the 180 degree phase shift caused by reflection. When the two components are equal in phase, they

add together to produce a stronger signal than would be produced by either component alone. At still greater heights, the two waves again arrive out of phase, and cancellation occurs. At extremely high frequencies, many cycles of change from null to maximum occur. At 3,000 MHz, for instance, the nulls are only two degrees apart. In the HF band, there are usually only one or two such cycles because of the greater wavelengths at these frequencies.

(c) The height of the transmitting antenna above the ground plays an important part in determining the shape and vertical orientation of the lobes. For instance, if the transmitting antenna is a quarter-wavelength above the ground, the wave goes through a 90 degree phase change in its path from the antenna to the ground directly below, a 180 degree phase change caused by reflection, and a further 90 degree shift on its way back from the ground to the antenna. Thus, the wave front is exactly in phase with the next succeeding wave front emitted from the antenna, and the maximum signal strength is directly above the antenna. These patterns of radiation are very important in ARDF, which operates against a combination of the direct and the ground-reflected wave components.

(d) At frequencies above 30 MHz, the wavelengths are shorter and the in-phase condition between the direct and ground-reflected wave components occurs close to the ground. Since the surfacewave component loses strength rapidly at these frequencies above 30 MHz, communications are largely by means of the combined direct and ground-reflected wave components. Reception can be improved by increasing the height of the receiver antenna to increase the path length difference between the direct and ground-reflected wave components to maximize the phase relationship between the two components. Since a full wavelength at 30 MHz is only 10 meters and decreases to 1 meter at 300 MHz, a small adjustment in

antenna height may produce the desired results by trial and error. It should be pointed out that whenever operations are conducted over terrain which inhibits ground reflection, such as areas covered by low brush or rocky desert terrain, the ground-reflected wave may be absent, and communications above 30 MHz will use the directwave component only. In essence, a very low percentage of a VHF signal is adequately reflected to enhance the DF effort.

(3) *Surfacewave*. This component travels directly along the surface of the earth (although it extends above the ground, its strength diminishes with increased height), and is affected primarily by the conductivity and dielectric constant of the ground over which it travels. The surfacewave is the primary component acted upon by ground-based DWDF systems below 30 MHz. The three most important factors of this type wave propagation are:

(a) *Frequency*. The lower the frequency, and therefore, the longer the wavelength, the greater the range. The LF and VLF frequency bands are used for extremely long-range communications. These frequencies are commonly used as navigational aids for ships. The MF range, which includes the standard broadcast band, can support moderate-range communications when the transmitting equipment is specially designed for groundwave propagation. Over sea water, this frequency range can be used for distances up to approximately 5,000 kilometers. In the HF band, wavelengths become shorter, and the dielectric constant and conductivity of the ground become the most important factors in surfacewave propagation. Regardless of ground conductivity, however, as the frequency increases, the groundwave range decreases. In the vicinity of 20 MHz, the groundwave loses strength very rapidly, and above 30 MHz, it is virtually nonexistent for purposes of practical communications and DF. Most military communications below 30 MHz operate in the 2-20 MHz range (predominantly in

the 1.5-8 MHz band) and rely mainly on skywave propagation. Groundbased DWDF systems working against such transmitters are actually receiving groundwaves which are unintentional byproducts of transmissions whose main energy is directed towards the ionosphere rather than along the surface of the earth (fig. 4-4.)

(b) *Terrain*. The electrical characteristics of the ground over which the groundwave component travels can affect its range considerably. Sea water is the best conductor, having a conductivity factor approximately 5,000 times as great as dry soil.

(c) *Polarization*. When the surfacewave is horizontally polarized, the earth has a short-circuiting effect which causes the wave to dissipate rapidly into the ground. For this reason, surfacewaves are generally vertically polarized. If a transmitted wave has some degree of both vertical and horizontal polarization, the horizontal portion will be quickly absorbed and only the vertically polarized part of the wave will travel any appreciable distance. Because of this, surfacewaves can be considered to be vertically polarized. This is an important point, since most DWDF systems employed against surfacewaves use vertical loop or monopole antennas which are designed to receive vertically polarized waves.

(4) *Tropospheric waves*. See paragraphs 2-14 and 2-15.

d. In the MF/HF range, the enemy transmitters against which DWDF is being conducted are likely to be communicating with another station hundreds of kilometers away by the skywave mode of transmission. The groundwave received by the DWDF team is generally an unintentional byproduct of a skywave transmission (fig. 4-4).

(1) This wave travels along the surface of the earth and can be strongly affected by the earth and natural or manmade objects on its surface. Obstructions between the transmitting antenna and a DF site can

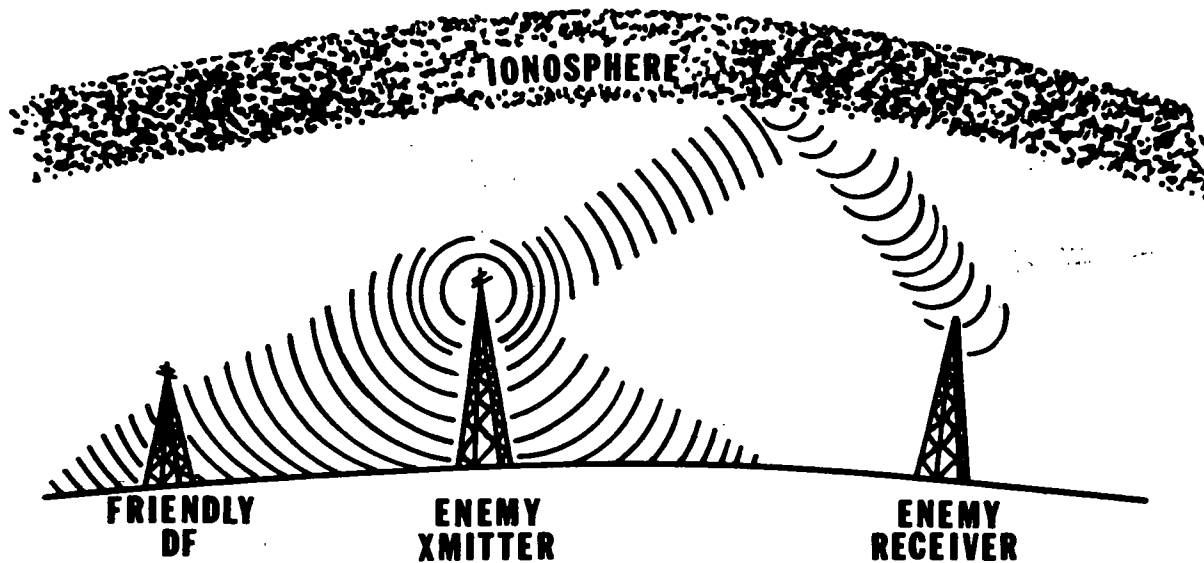


Figure 4-4. Groundwave DF.

cause the wave to deviate from a straight-line path and introduce wavepath errors of varying degrees.

(2) The distance these groundwaves can be received by a DWDF set is subject to extreme variations and is affected by such factors as transmitter power output, antenna type, terrain, manmade objects, and operating frequency. Advance estimates of expected groundwave range in a given environment can be made if some knowledge of the enemy's communications equipment and operating techniques is available; however, some actual operating experience in each situation is usually required before reliable range estimates can be made.

4-3. The Baseline and Baseline Distance.

The establishment of a suitable baseline is affected by tactical, strategic, and technical considerations. A direction-finding baseline is identified as the imaginary line or axis along which the DF equipment of a DF network is deployed. Essentially, there are two types of

baseline configurations utilized for deployment of a DF network; concave or straight, and convex. The baseline distance is that straight line distance that separates the two outermost DF stations or sites. As a rule of thumb, a DF network fix capability is equal to the distance of the baseline measured from the center of the imaginary line joining the two outermost DF sites. For example, if the DF baseline is 80 km in length, the net location capability is 80 km in depth. Tactically, the deployment and movement plans of the friendly unit in whose area of operations the DWDF net is established will determine which areas are available for the siting of the DF equipment. However, the target area to be covered, depending upon a technically acceptable environment, will dictate the baseline configuration that is employed in any given situation.

a. *Concave.* If it is expected that the target locations will be in a rather compact, narrow but deep, frontal area, it is best to locate the direction finders on a concave or

even straight base line (fig 4-5). With this baseline, the azimuth angles are satisfactory at longer ranges and excellent at short ranges.

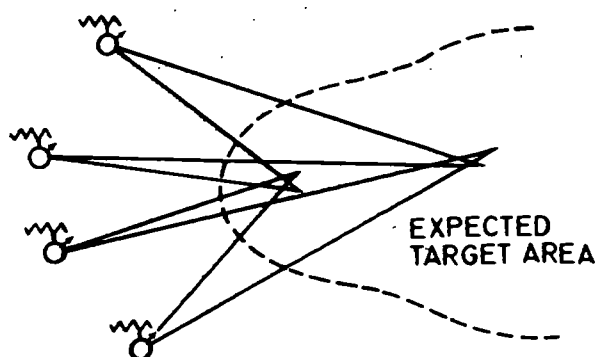


Figure 4-5. Concave baseline.

b. *Convex.* If target locations are anticipated to be located over a wide flanking, short-in-depth area, a triangular or convex (quadrilateral) baseline is suitable (fig 4-6). Using a convex baseline in this situation provides a reasonable azimuth angle over a wide front. It is probable that the convex baseline will satisfy the average situation.

4-4. Baseline Considerations.

The physical security of the DF site presents a combination of technical and tactical problems. Sites that are most suitable from a technical standpoint may be tactically undesirable, and vice versa. In many cases, a technically desirable site may be located in a risky area, and a suitable defensive perimeter must be established. If barbed wire is required in the vicinity of the DF site, or if armored vehicles are stationed near the DF antenna, these metallic objects will introduce DF errors that may completely negate the site's original technical advantages. DWDF equipment is subject to serious errors caused by poor siting. Siting criteria, which are applicable to all DF efforts, will be discussed in detail in a later paragraph of this chapter. While it is difficult

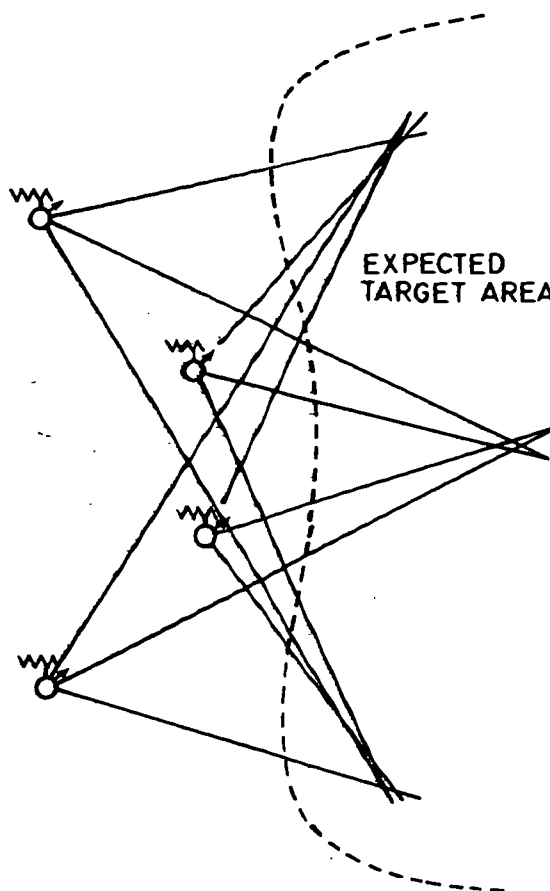


Figure 4-6. Convex baseline.

to locate a technically ideal site, it is essential that the siting criteria which follows be adhered to as closely as possible.

4-5. Terrain Considerations for Wavepath.

The terrain on which both the DF sets and the target area are located is an important factor in DWDF operations. In favorable terrain, such as flat areas with few obstructions, all of the DF sites may have a clear electronic "view" of the target area. The establishment of the baseline is largely a matter of placing the DF sets so that good bearing angles for triangulation within the

target area are possible. Ideally, each of the sites should have an unobstructed wavepath between the DF antenna and any point within the target area. In most cases, however, this is not possible. Sites should be arranged so that portions of the target area that are "masked" to one or more sites can still be covered by at least three other sites. This is similar to setting up interlocking fields of fire for weapons, except that in the case of DF sets, each area must be covered by three "lines of fire" instead of one or two (fig. 4-7).

4-6. Masking of Transmitters by the Enemy.

There are some situations in which the enemy can take advantage of terrain features to mask his communications from friendly groundbased DF sets. Such a situation is illustrated in figure 4-8. The transmitting antenna, being hidden behind a hill is electronically masked from the DF sites, yet is able to communicate effectively with his outstation. Although this type masking is most effective in line-of-sight communications, the possibility must be considered whenever the terrain features in the enemy's area of operations afford the opportunity.

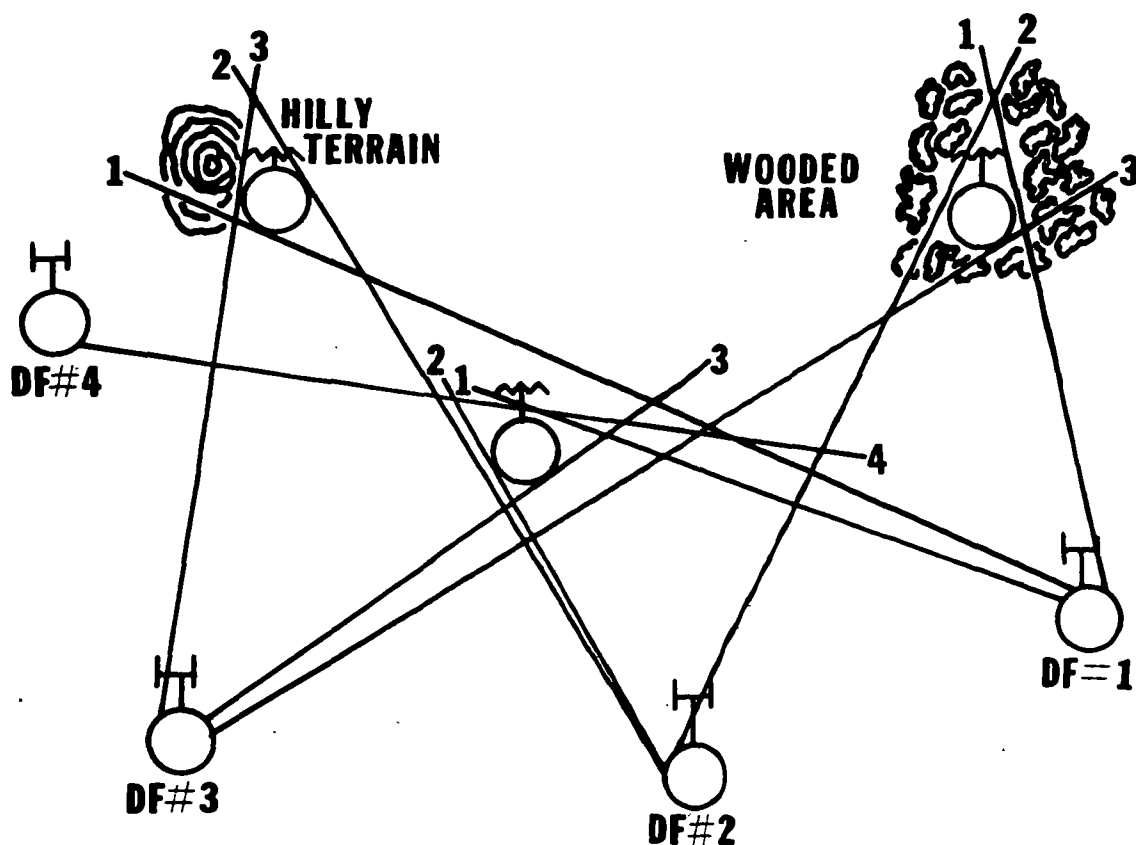


Figure 4-7. DWDF net with curving baseline.

4-7. Limitations of Baseline Establishment.

In some situations, conditions may be prohibitively unfavorable for DWDF operations because of impossible terrain conditions, unusual propagation factors, or baseline restraints. An example of a prohibitive baseline limitation is an amphibious operation with an assault on a very narrow beachhead. In this case, the area under friendly control is too small to establish an effective baseline, therefore, effective DF cannot be employed. In such a situation, it would be necessary to rely on ARDF support until the beachhead is expanded to accommodate a suitable baseline.

4-8. Map Reconnaissance for Establishing DWDF Nets.

The most important step in setting up the DWDF net is thorough planning of the operation. Maps of the area must be carefully studied to find favorable site locations that present the best possible wavepaths from the target areas. The size and shape of the deployment area must be considered, as well as the estimated transmission range of enemy transmitters. The number of DF sets available for deployment will heavily influence the planning estimates. Sites must be in good radio reception areas and as far removed as possible from all obstructions, particularly metallic objects. Even under particularly unfavorable conditions, acceptable DWDF results can be obtained if the operation is carefully planned, with proper attention paid to the fundamentals of DF site selection and wavepath considerations.

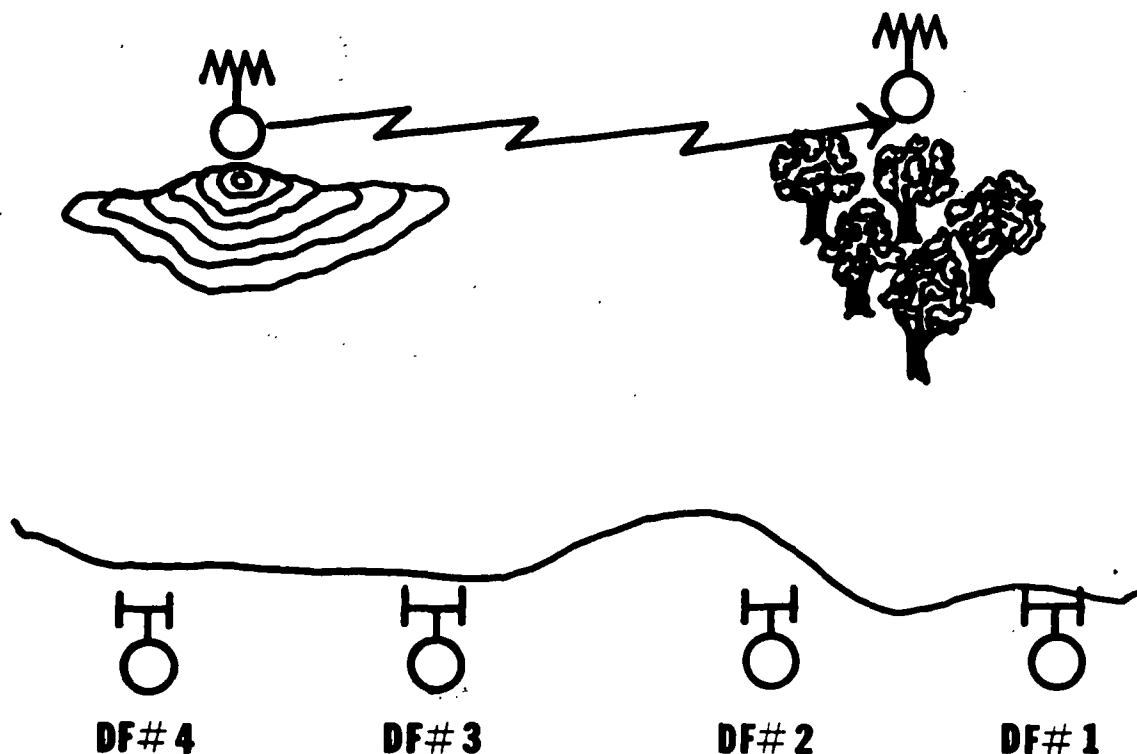


Figure 4-8. Enemy transmitter masked to friendly DF stations.

Section III***SKYWAVE DIRECTION FINDING*****4-9. SWDF Factors.**

This discussion of SWDF will deal only with the acquiring of bearings from skywaves arriving at DF antennas. The tactical and technical requirements discussed in paragraph 4-2 for DWDF site selection will also apply to most SWDF sites except where friendly DF sites are installed in CONUS or countries friendly to the United States and where physical security would not be a major requirement. DF sites which deal primarily with SWDF are quite often designed to provide strategic coverage over vast geographical areas, such as an entire continent. Nets of this nature will frequently have sites scattered along a baseline thousands of kilometers in length.

4-10. The Baseline.

Site acquisition for strategic DF nets in foreign countries will usually be a joint effort with the host country. The DF planner gives the site requirements to a consular office or an embassy which negotiates with the host country for the site. For those installations to be equipped with large CDAA, approximately 40 acres will be needed at each site. For smaller equipment sites, the baseline will usually remain in land areas where tactical superiority is exercised by friendly forces. Siting criteria, discussed in paragraphs 4-2 through 4-6, apply to SWDF as well as to DWDF.

Section IV***AIRBORNE RADIO DIRECTION FINDING*****4-11. General.**

In the ARDF effort, the aircraft is actually the DF site, consisting of a combination of dipole antennas, a coupling system, receivers,

integrated equipment that will resolve the ambiguity of the incoming RF signal, and air-to-ground communications equipment.

4-12. Concept of Employment.

Within TOE limitations, aviation companies with the ARDF capability are deployed so their product is available to all combat echelons. Tasking is done through a central control section at the supported command level. These ARDF aircraft are used to supplement groundbased collection systems by providing an airborne DF platform to extend the radio horizon. The mission of ARDF involves acquisition and location of targets within the supported commander's area of interest.

4-13. Aircraft.

Normally, the aircraft deployed for tactical ARDF missions is of a standard type modified to accommodate ARDF equipment.

4-14. Equipment Employed in ARDF Operations.

In addition to the normal complement of installed antennas, the ARDF aircraft will have some combination of the following antennas: two wing-mounted dipole antennas, two inboard nacelle dipole antennas, two horizontal stabilizer dipole antennas, one fuselage-mounted spaced-loop antenna, and a whip antenna used to search for targets. Some will also have a fuselage-installed antenna group for use with the radar navigational system. Other equipment necessary for ARDF is:

- a. Direction-finding receiver.
- b. C-11 gyroscopic compass system.
- c. C-12 gyroscopic compass system.

d. Radio Magnetic Indicator (RMI).

e. Inertial navigation system.

4-15. Crew Requirements.

The crew for a normal mission on an ARDF aircraft would consist of a pilot, a copilot, and one or more operators depending upon equipment on board.

4-16. Mission Configuration.

ARDF aircraft are configured with equipment to cover various frequency ranges. The aircraft configuration used would depend upon the supported commander's intelligence needs.

4-17. Navigational Requirements in ARDF Operations.

The pilot is responsible for the safety of his aircraft and accomplishment of the mission. To partially satisfy this requirement, he must know where he is at all times. For routine flying, arrival within one quarter of a mile of the destination is sufficiently accurate. He can adjust any minor navigational inaccuracies in the traffic pattern at his destination. Unless suitable adjustments for aircraft location are made, this criterion is intolerable in ARDF operations. The pilot must always know the precise location of his aircraft over the ground using dead reckoning and referring to visible landmarks on the ground and on his charts. New aircraft have instruments that operate in conjunction with satellites and ground stations which keep the pilot informed of his precise location.

4-18. General Operating Environment of ARDF Units.

Each aviation unit requires a base of operations from which the aircraft can fly. The aviation unit providing ARDF support requires an adequate operations area and a secure communications facility through which mission assignments can be received and results reported.

4-19. Flight Considerations for ARDF Operations.

Before the mission flight, the aircrew is given a thorough briefing of the target area. The current artillery advisory, in the mission area and enroute, is carefully studied because the ARDF aircraft operate at altitudes low enough to be vulnerable to high trajectory firing. The pilot then decides whether to fly a direct route or make some detour to avoid artillery and hazardous terrain. The pilot notes any emergency landing areas close to the intended route and studies the terrain features on the chart for suitable basepoints, such as distinctive patterns of railroad tracks or roads, sharp bends in rivers or trails, quarries, small lakes, and other easily identifiable terrain features.

4-20. Integration of Results.

Tasking, plotting, and reporting is generally handled within the channels that regularly process DWDF and SWDF reports. ARDF results on high priority targets in which a tactical unit has pressing and immediate interest may be passed directly to the supported commander by secure means. Although passed directly, the results will still be processed with the results from other DF efforts through a central control or plotting facility. ARDF contributes to the overall effort in much the same manner as the other efforts previously discussed.

CHAPTER 5

Direction-Finding Techniques

Section I MAPS

5-1. Use of Map Projections with DF.

The basic method of DF plotting consists in the measurement, at a receiving or centralized plotting station, of the angle between the direction of a predetermined reference line (usually magnetic or true north) and the direction from which the electromagnetic waves arrived from a distant transmitting station. The results are plotted and evaluated on a map. For this reason, the more important types of map projections are explained below.

5-2. General.

a. Definition. A map as used for DF plotting, is a graphic representation of a portion of the earth's surface. Although drawn to scale, no map is absolutely accurate since it represents the earth as a plane or flat surface. Accuracy depends upon the method used in making the map, and certain properties must be sacrificed to obtain other desirable features in accordance with its specific use.

b. Introduction. No portion of the earth's surface can be spread out into a flat plane without some "stretching" or "tearing." This is illustrated by attempting to flatten either the cap of an orange peel or a portion of a hollow rubber ball. The outer portion must be stretched or torn before the central

part will flatten. However, there are some surfaces which can be spread out in a flat surface without stretching or tearing; these are called developable surfaces. Those surfaces which cannot be spread out in a flat surface, such as a sphere, are called nondevelopable surfaces. Two well-known developable surfaces are the cone and the cylinder. If a paper cone is cut from the base to the apex, the conical surface can be spread out in a flat surface without tearing or stretching (Capital A, fig. 5-1). If such a cone is flattened, any line or curve drawn on it will have exactly the same length as before. In the same manner, if a cylindrical surface is cut from base to base, the whole surface can be rolled out into a plane or a rectangle (Capital B, fig. 5-1). In this case there is no stretching or tearing of any part of its surface.

5-3. Reference Points on a Spheroid.

On a spheroid such as the earth, it is necessary to have some points or lines of reference so

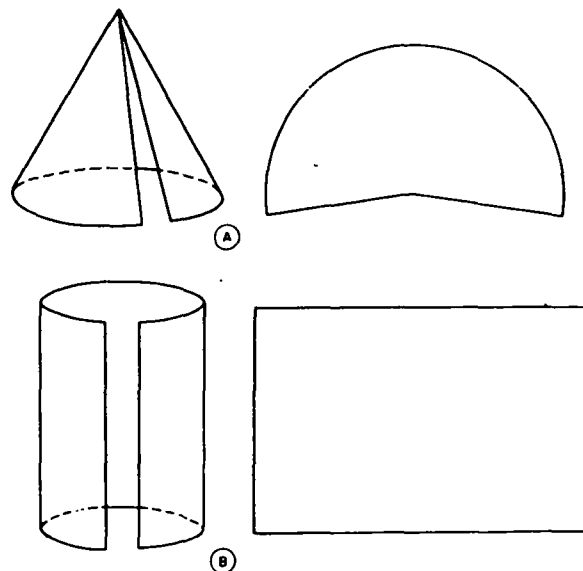


Figure 5-1. Cone and cylinder, developable surfaces.

that any point may be located with respect to them. Places on the earth are located by latitude and longitude, which form a network of lines running true east and west (parallels of latitude) and true north and south (meridians of longitude).

a. *Derivation of Reference Points on a Spheroid.* The ends of the earth's rotational axis are called the North Pole and the South Pole. With these as starting points, assume the earth is divided into two equal parts by a plane perpendicular to the axis midway between the poles. The circle formed by the intersection of this plane and the surface of the earth is the equator and divides the earth into the Northern Hemisphere and the Southern Hemisphere. Any circle upon the earth which divides it into two equal parts, such as the equator, is called a great circle (see fig. 5-2). It is customary in the United States to divide these great circles into 360 equal parts called degrees.

(1) *Meridians.* As shown in figure 5-3, any number of great circles can be drawn through the two poles, and each will cut the equator into two equal parts. Each circle may be divided into 360 degrees, with the equator 90 degrees from either pole. These great circles are called meridians.

(2) *Establishing meridians of longitude.* To further reference a point, it is necessary to number the meridians east and west from an established location. Most countries have adopted the meridian passing through the Greenwich Observatory in England as the zero meridian, or the prime meridian (0 degrees). The degrees of longitude are counted from 0 to 180 degrees east and west (fig. 5-4). The great circle that passes through the poles and Greenwich, England, is called the prime meridian on one side of the globe, and the 180th meridian on the other side, since at this point it is both 180 degrees east and west of the prime meridian. Thus, east-west reference points are provided.

(3) *Establishing parallels of latitude.*

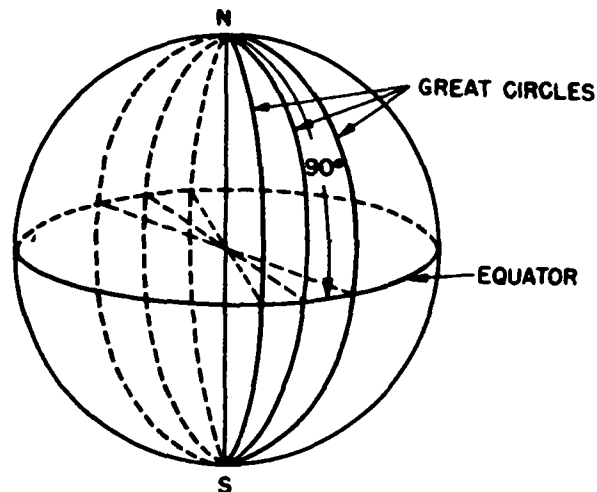


Figure 5-2. Great circles.

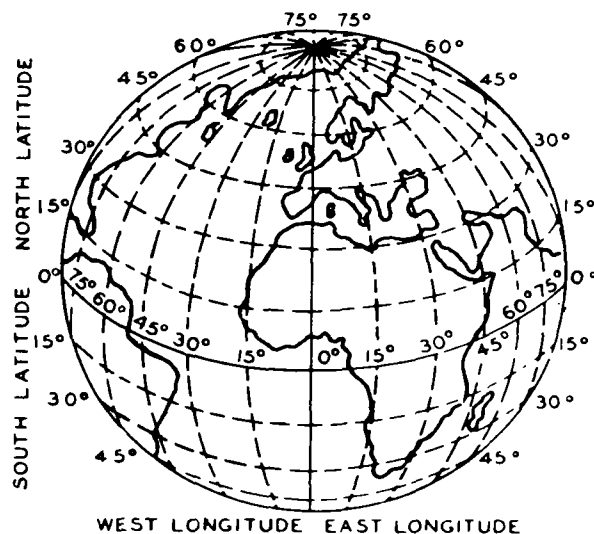


Figure 5-3. Projection of a sphere showing the arrangement of longitudes and latitudes.

Assume that on one of these meridians a point is taken 70 degrees north of the equator, and a plane is passed through this point perpendicular to the north-south axis

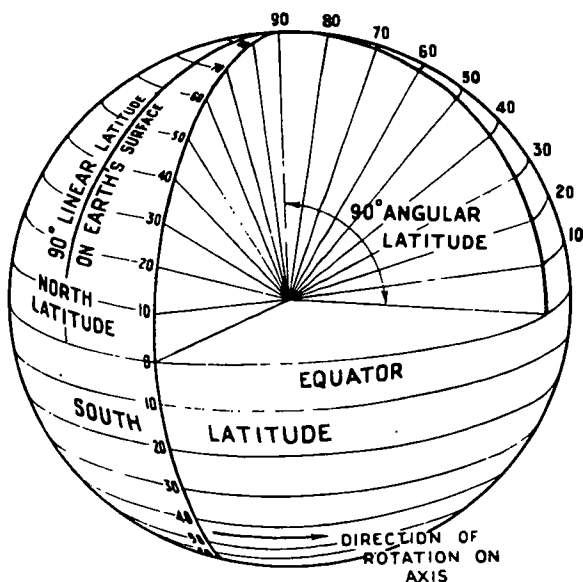


Figure 5-4. Diagram of the globe indicating the derivation of longitude.

(parallel to the plane of the equator). The intersection of this plane and the surface of the earth will form a small circle called a parallel of latitude (fig. 5-5). Every point on this circle will have a latitude of 70 degrees north. Other such circles can be formed at 20 degrees, 40 degrees, etc. Thus, since the equator was drawn as a great circle midway between the poles, a point north or south with reference to the poles can be located.

b. Initial Problem of Map Projection. A sphere constructed with meridians and parallels on it represents the earth with its imaginary meridians and parallels. As previously stated, a sphere is nondevelopable. Therefore, the problem of map projection is one involving a systematic drawing of lines representing meridians and parallels on a flat surface, either for the whole earth, or any desired portion.

5-4. Selecting a Type of Map Projection.

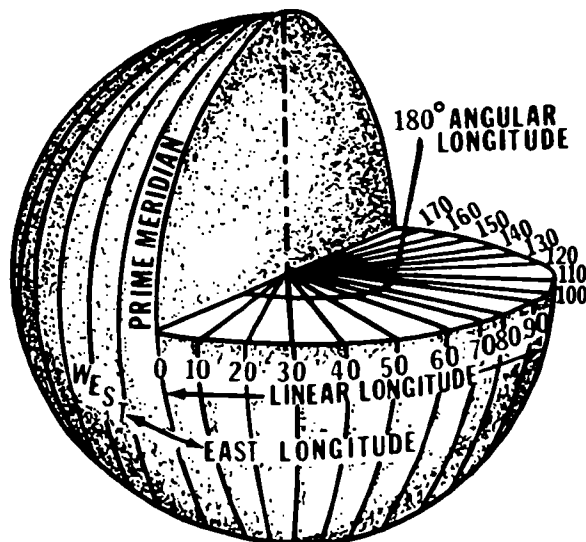


Figure 5-5. Diagram of the globe indicating the derivation of latitude.

The spheroidal shape of the earth cannot be represented on a plane without distortion, therefore, a compromise of desirable properties to obtain the most practical features for a specific use must be made. Many different types of map projections have been devised, each having special merits for their intended use, while compromising other features. The map projections used for DF plotting must be of a type that a straight line from a given point will indicate the true azimuth. Three map projections commonly used for DF plotting are:

a. Universal Transverse Mercator Projection. The Universal Transverse Mercator (UTM) system (fig. 5-6) is the most commonly used map projection method for military purposes. It can be easily oriented for combat situations and readily used with a compass to find a true azimuth from any given point on the map. This system, makes it possible to plot from point to point using a

straight line called a rhumb line. This rhumb line may be used to determine latitude and longitude of any point along its path, up to 300 kilometers. This is of great importance because it is only through use of a map projection system of this type that a flat presentation of a globular object may be displayed with the distortion minimized.

b. Gnomonic Projections.

(1) The gnomonic projection is the most commonly used map projection system for long range DF plotting. It is particularly

useful when plotting across great expanses of ocean.

(2) A gnomonic projection of the earth is derived by projecting the surface of the globe, from its center, upon a planar surface. This projection method represents all great circles as straight lines, and is the projection's chief merit. This property is important in DF, because the shortest route between two points (a straight line) is always a portion of the arc of a great circle. Radio waves travel more or less on great circle routes.

(3) The mathematical limit of this projection is a hemisphere. The practical limit is a quarter of the globe (90 degrees) since the distortion beyond that point becomes severe.

c. Equatorial Projection. This projection was rarely used in earlier DF efforts. However, with the installation of large fixed sites with DF multiband capabilities, this projection is essential for maximum accuracy and convenience. With the development of computer technology, the computer produces such projections from any given reference point. This projection has a relatively small scale error if it is not extended beyond a hemisphere. It is possible to show the whole earth, although distortion increases rapidly toward the perimeter. Figure 5-7 is a map representation of this projection centered on New York.



Figure 5-6. Mercator projection on a cylinder indicating method and showing polar distortion.

5-5. Aeronautical Charts.

Another type of map encountered in the plotting of DF results is the aeronautical chart. The major difference between aeronautical charts and standard Army maps is that the grid lines in aeronautical charts are straight and are oriented to true north, and the particular areas in which magnetic variation occurs are indicated by broken magenta-colored lines which follow the exact electrical variations in the earth's surface. These lines, called isogonic lines, waver and

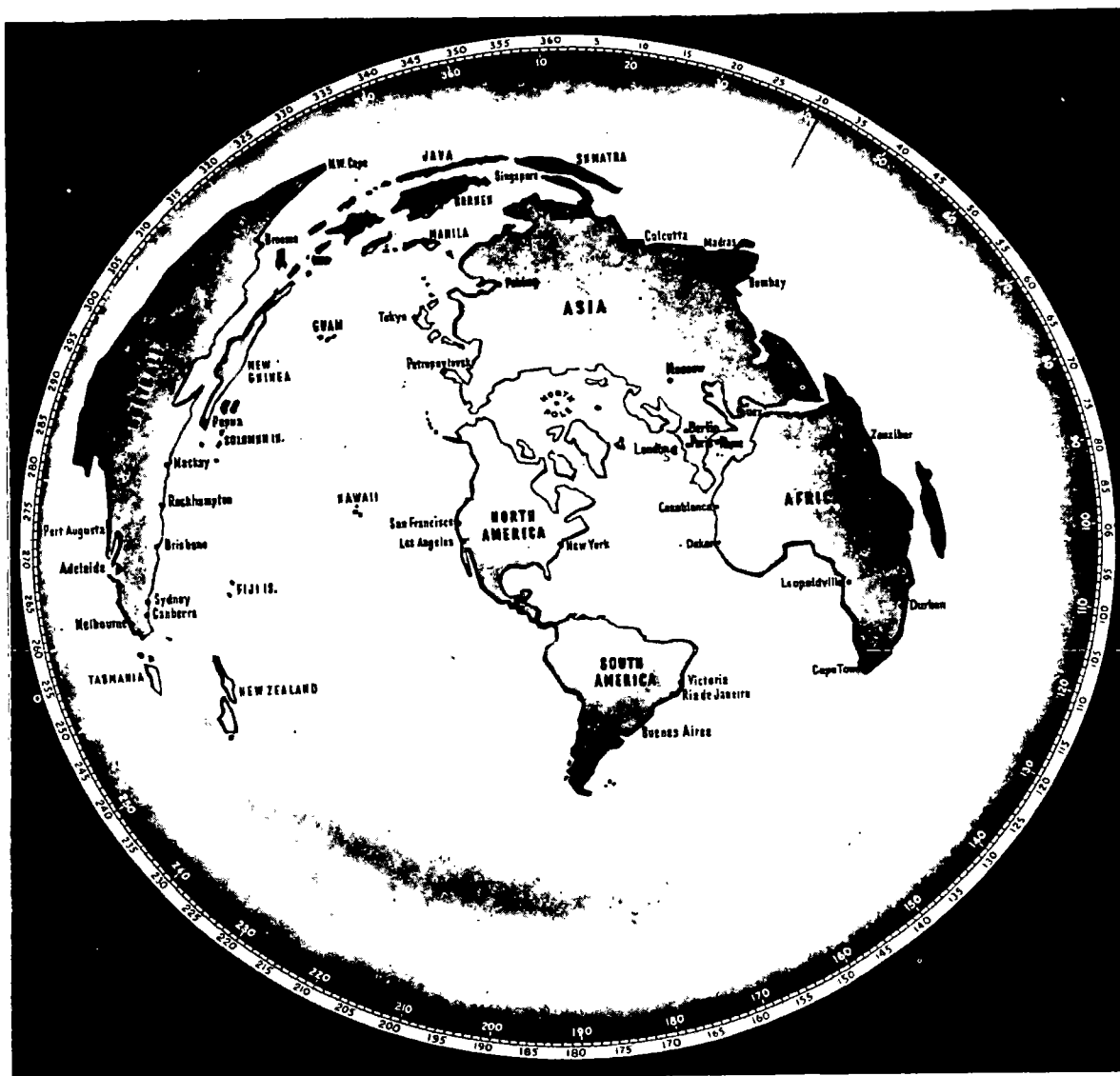


Figure 5-7. Azimuthal equidistant projection centered on New York.

slant to follow the electrical fields which they designate. Where true north and magnetic north are almost identical, these lines are called agonic lines, and there would be no deflection of the compass needle from true north indicated by the grid lines. As electrical fields in and around the earth do not respect the orderly requirements of the map makers for maximum accuracy, the user must

“average” the variation depending upon the distance he may be from an isogonic line.

5-6. Magnetic Variation and Use of the Compass Rose.

Magnetic north and true north do not coincide. True north and south (the poles) are used as the chart poles because they are fixed

and unvarying. Magnetic north is some 650 kilometers south of geographic north, and is constantly changing its exact location.

a. Variation. When a compass needle points north, it is not pointing to the north of the chart (true north), but rather to magnetic north. The amount of separation between these two points is called variation, and is expressed in degrees. The amount of variation differs with the locality, since it follows the magnetic channels between the poles. It may vary east or west of the true meridian, or it may not vary at all (fig. 5-8). This variation is a continually changing phenomenon which could not be represented on any map or chart perpetually. Therefore, maps should be obtained with the latest variations posted before planning any DF plotting effort.

b. Use of the Compass Rose. The amount of variation for each locality on

charts and maps is indicated by either a compass rose, a declination diagram, or a narrative statement, depending upon the age and type of map. A compass rose is a double graduated circle, the outer one marked in degrees and the inner one marked in compass points. Figure 5-9 illustrates the compass rose on a 1939 map. The outer circle, which is stationary, is oriented to true north. Its zero degree is true north. The inner circle is oriented to magnetic north for the year indicated in the center of the compass rose diagram. The difference between the two points is the variation in the year indicated in the center.

(1) The variation since the year the chart was published is obtained by multiplying the annual increase or decrease, indicated in the lower half of the center of the rose, by the number of years elapsed between printing and reading. Therefore, in figure 5-9, the variation in the year 1939 was

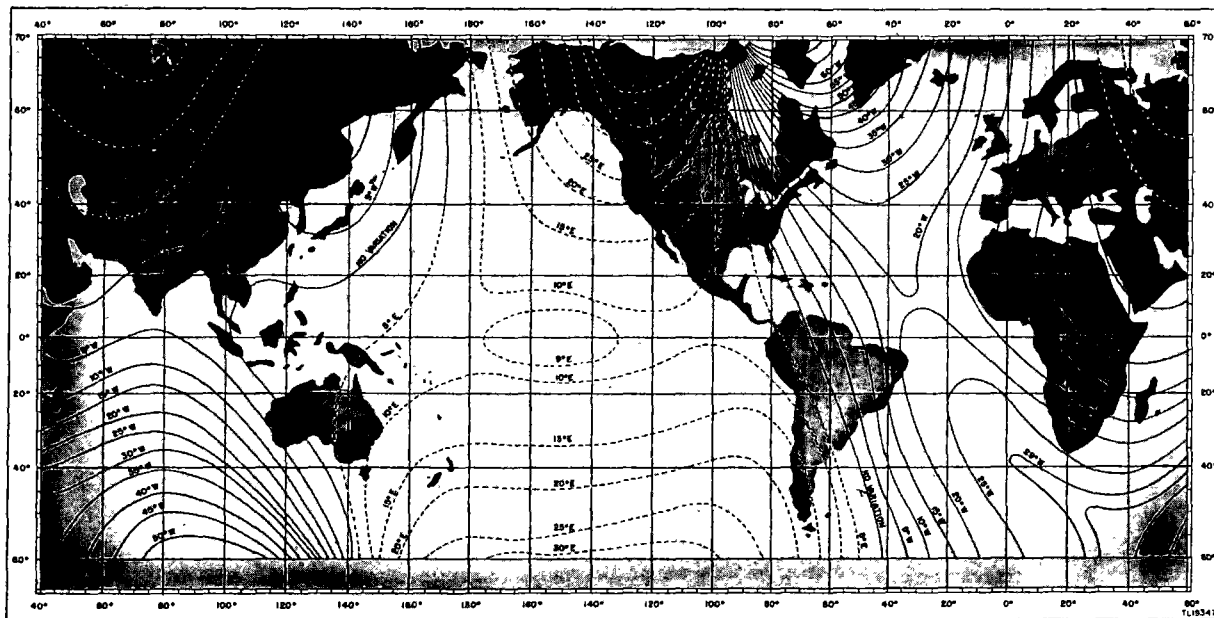


Figure 5-8. Map of the world showing typical zones of magnetic variation.

uncharted or inaccurately charted, and older maps may be the only references available.

5-7. Declination Diagrams.

a. A declination diagram is placed on most large-scale maps to enable the user to orient the map properly. The diagram shows the interrelationship of magnetic north, grid north, and true north. On medium-scale maps, declination information is shown by a note in the map margin.

b. Declination is the angular difference between true north and either magnetic or grid north. There are two declinations, magnetic and grid. Magnetic north, grid north, and true north (fig. 5-10) are indicated on the diagram by a half arrow, straight line, and star respectively. Since it is not the intent of this manual to discuss basic map reading, FM 21-26, Map Reading, should be used as a basic reference.

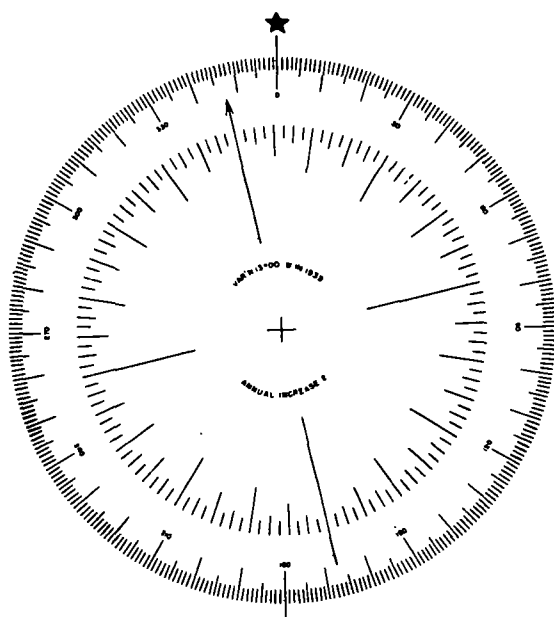


Figure 5-9. Compass rose.

13 degrees 00 minutes W and the variation increased 2 minutes each year, as indicated in the center of the rose. Therefore, the variation in 1946 would equal 7 (number of years between 1939 and 1946) times 2, or a total variation of 13 degrees 14 minutes W. If the variation had indicated an annual decrease, the amount would be subtracted from the 1939 variation.

(2) When a true direction reading from a map is changed to a magnetic direction, easterly variation is subtracted from the true course indicated, and westerly variation is added. A memory aid, in the form of a simple rhyme is, "East is least (subtract) but west is best (add)." The reverse is true when changing from a magnetic to a true course reading.

(3) The compass rose variation indicator is not used on many maps today. An explanation is included for its use since there are many parts of the world that remain

Section II

DF SITE REQUIREMENTS

5-8. General.

Whenever a DF site is set up in a new location, its antennas must be precisely oriented to a known reference point to produce an accurate measurement of the arrival angle of a wave front. Without this accuracy, the plotting of reported bearings would be valueless. DF stations of the US Army have their antennas oriented to true north. To establish a true north reference line on the map of the area in which the DF site is being erected, it is common to use celestial bodies and satellites for maximum accuracy. Alternatively, field expedient methods may be used. Chapter 5, FM 21-26 explains in detail those field expedients which may be used to determine the direction of true north.

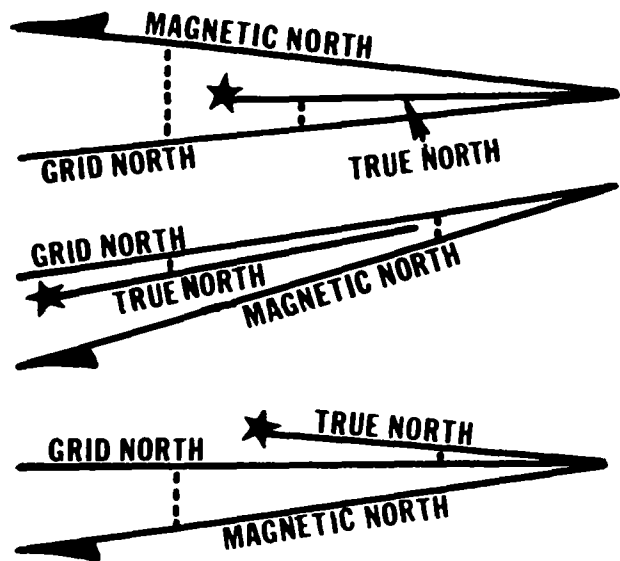


Figure 5-10. Declination diagrams.

5-9. Siting Errors.

Siting, as well as orientation, of DF antennas is extremely important in obtaining maximum DF accuracy. Since radio waves can be deflected from their paths by various obstacles, and DF equipment can only measure the angle of arrival where the DF antennas are located, the DF set should be positioned where the wavepath is least susceptible to outside influences. Then the DF set will give the most accurate representation of the true direction of wave travel. Obstructions in the near vicinity of the site are particularly objectionable; the closer the obstruction is to the DF site, the greater its adverse effect on the site. DF errors caused by obstructions in the vicinity of the DF site are known as site errors. Figure 4-2 illustrates site errors caused by reflecting or radiating objects located near the DF site.

5-10. Site Criteria.

5-8

a. The area should be substantially flat for approximately 90 meters from the DF antenna and have no more than a gentle slope for equal times that distance.

b. The area should be the highest level area in the vicinity. A site in a valley is usually unsatisfactory.

c. Mountainous or hilly country should be avoided.

d. The area should be as far as possible from the shore line of large bodies of water (at least 5 wavelengths of the lowest frequency to be measured). If the installation must be made on or near the coast, the flattest area should be selected and the DF antenna should be oriented so that the azimuth arc to be measured is as nearly perpendicular to the coast as possible.

e. The earth at or around the site should have uniformly high conductivity and moisture content. Areas uniformly covered with grass or vegetation usually meet this requirement. Rock or sandy soil is poor as a DF site. Areas having low conductivity are preferable, however, to areas having high conductivity spotted with rock formations, sand, or a varying moisture content.

f. Regions where there are abrupt discontinuities of the earth should be avoided. Sharp changes in terrain elevation usually indicate the presence of rock or mineral outcroppings, or underground streams.

g. The site should be removed from tall trees, buildings, wire fences, power or telephone lines, radio antennas, railroad tracks, buried metal conductors (cables and pipelines), sharp ground contour changes (mountains, cliffs, and ravines), chimney stacks, water towers, rivers, lakes, and streams.

h. Distances to be maintained between the DF site and these obstructions to minimize their effect on accuracy are listed in table 5-1.

Table 5-1. Preferred Distance from Obstacles.

<i>OBSTACLES</i>	<i>DISTANCE TO BE MAINTAINED</i>
Scattered trees and single small buildings	185 meters
Wire fences	275 meters
High cliffs and deep ravines	1.6 kilometers or farther
Buried metallic conductors	275 meters
Chimney stacks and water towers	450 meters
Railroad tracks and overhead conductors (utility lines and antennas)	450 meters
Mountains	10 to 50 kilometers
Rivers, streams, and lakes	550 meters

5-11. Comparison of DWDF and SWDF Site Establishment.

In establishing large, fixed-installation DF sites, all of the technical considerations can usually be met. Tactical DF sites, however, present more of a problem since the areas available for sites are fewer, and such factors as physical security and logistical support become predominant considerations. Once a site has been installed, it is necessary to ensure that it remains free of obstructions. A restricted zone should be established for a distance of 150 to 300 meters in all directions from the center of the DF antenna array. This zone must be kept free of all construction and material storage. As a minimum, this area must be kept completely free of metallic buildings, vehicle parks, and other obstructions listed in the above table.

5-12. Site Testing.

In addition to the physical criteria specified previously, additional tests should be made on the DF site if time and the tactical situation permit.

a. Electrical Inspection.

(1) *Noise measurement.* Measure the noise level with a field strength meter or comparable equipment, at the major frequencies on which the DF set will be operated. If the equipment is to be used over a band of frequencies, measurements should be made throughout the band. For a suitable DF site, the noise level (other than temporary atmospheric noise) should be low, otherwise many signals of interest will be lost.

(2) *Field pattern.* This test is made to determine uniformity of reception for the DF site. An explanation of this test was detailed in paragraph 3-1a. Although the directivity of an installed antenna was discussed in the polar diagram section, the reader can compare the discussion with figure 5-11 and reasonably deduce how the test for uniform reception of the chosen site is made with the target transmitter and field strength meter instead of a receiver. The field strength measurements for each position of the target transmitter (as indicated in fig. 5-11) must be taken with all measurements marked accurately. Each frequency must be plotted on rectangular coordinate paper relating field strength to azimuth, and the resulting graph should be substantially a straight line. Any irregularities indicate an absorption or reflection of the wave which would affect the accuracy of the DF. If the variations exceed 25 percent of the average field strength, especially in azimuth arcs where maximum accuracy is desired, the site is unsuitable for DF. If the visual and electrical inspection discloses no objection to the use of the site, the DF antennas may be erected.

b. Tactical Requirements for Good Sites. In addition to security, other factors which should be considered are:

(1) Does it afford convenient approaches for vehicles?

(2) Is it located at a practical distance from the supply and ration point?

(3) What is its proximity to suitable bivouac areas?

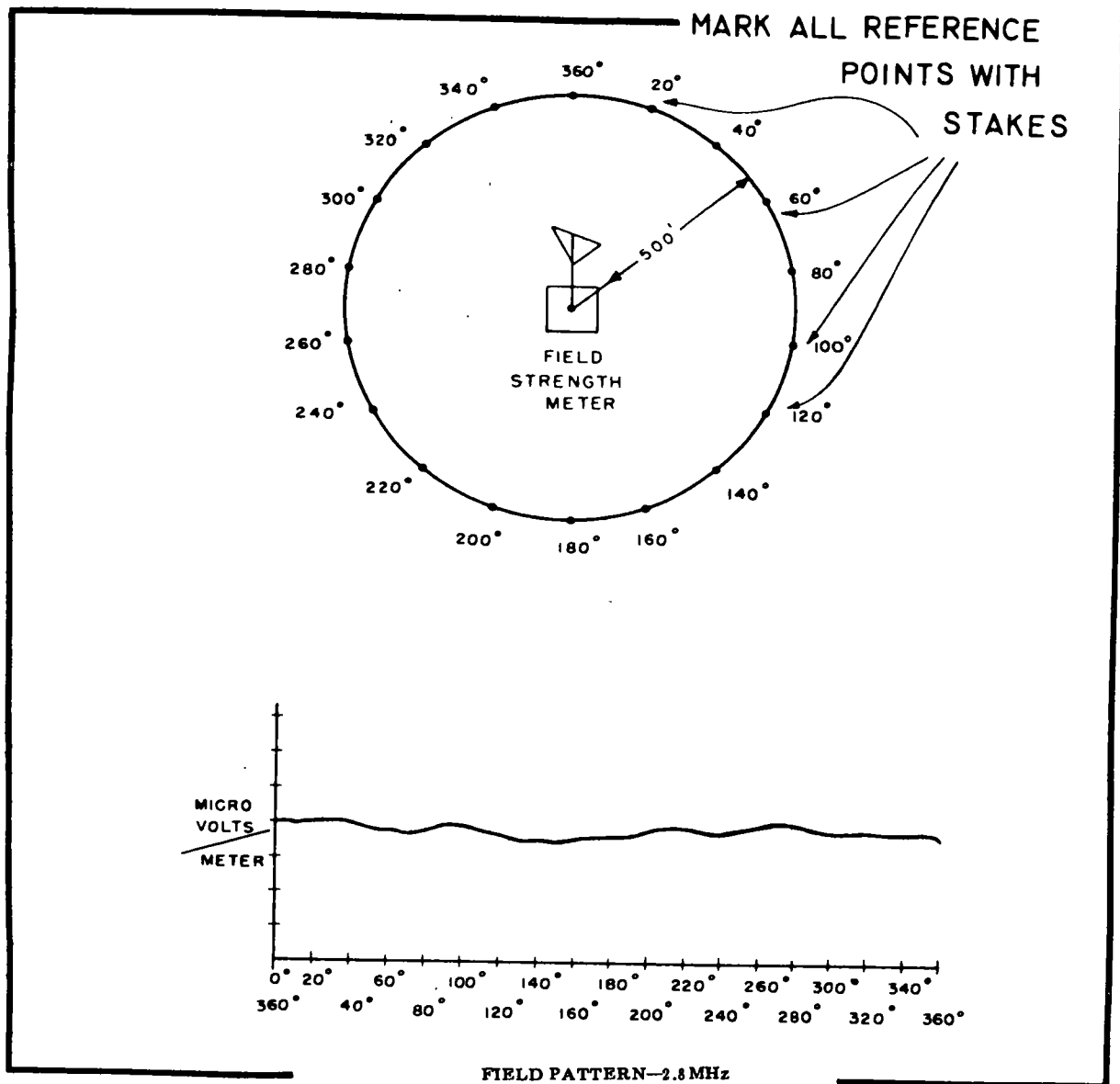


Figure 5-11. Field pattern.

5-13. Improvement of Sites.

The DF site selected, although the best possible, may be far from ideal. Nevertheless, definite measures for improving the site from a technical viewpoint can be undertaken. Areas which are not substantially flat for at least 90 meters from the DF antenna can be leveled off with a bulldozer or grader. If it is

impractical or even impossible to level the entire area for 360 degrees coverage, at least those areas within the azimuth arc of primary interest should be flattened. Natural objects such as trees and low vegetation should be cut down or uprooted. Manmade objects and personnel not actually engaged in operating the site should be kept away from the antenna system. Increasing the conductivity

of the ground is another measure that will aid in the overall efficiency of the system. Most DF antenna systems that are not manpacked or vehicular transportable are issued with a counterpoise, which are grounding devices installed under each dipole.

5-14. Periodic Checking of DF Equipment and the Site Selected.

a. Checking Instrumental Calibration and Adjustment. The various calibrations and adjustments of DF equipment described in technical manuals must be performed at regular intervals to ensure continued satisfactory performance and accurate results. Checks should be made at frequent intervals.

b. Daily Check of DF Accuracy. Take daily bearings on known transmitters to ascertain if the accuracy or calibration of the DF site is acceptable. Any appreciable deviation of the DF bearings from the known bearing, or the ones normally obtained, should be investigated immediately.

Section III DF ERRORS

5-15. General.

This section discusses the various types of errors which may be encountered in DF applications. How these errors may influence the accuracy of the equipment is explained, and how to minimize the influence of these errors to ensure optimum performance is included. An understanding of the information contained in this section will enable the operator to analyze the inferior performance of a DF set, to select and segregate the type or types of errors causing the inferior performance, and, in some cases, to decrease or eliminate the effects of these errors. For purposes of explanation, the various types of errors are grouped as source, path, polarization, site instrumental, and operator errors.

5-16. Source Error.

This error is introduced at or near the transmitting station. It may be caused by the particular type of directional antenna employed, or by ground conditions at the transmitter site which alter the normal radiation pattern of the antenna. If the DF site is more than 15 kilometers away from the transmitting antenna, the magnitude of the source error is usually small compared to other errors. It is, therefore, seldom a contributing factor to the overall accuracy of a DF bearing.

5-17. Path Error.

This is caused by deviations of the radio wave from the great-circle path between the transmitting antenna and the DF site. This deviation is caused by the radio wave being absorbed, reflected, reradiated, refracted, or a combination of these factors. The more important sources of path error and methods of reducing these errors are:

a. Scatter. In some instances, a small portion of the radio wave entering the ionosphere is scattered instead of being gradually bent and returned to the earth. This scattered radiation may be projected in any direction, and returns to earth at random angles (fig. 5-12 and 5-13). This accounts for signals sporadically received in regions that are normally in the skip zone of an HF transmitter (fig. 5-14). Under ordinary operating conditions, errors caused by the reception of scattered waves are not likely to occur. In some cases, however, when a powerful transmitter using a highly directional antenna is transmitting in a direction other than that of the DF site, an azimuth reading taken on this transmission may cause the apparent location of the transmitter to be somewhere along the course of its directed beam rather than in its correct position. This is caused when receiving a wave

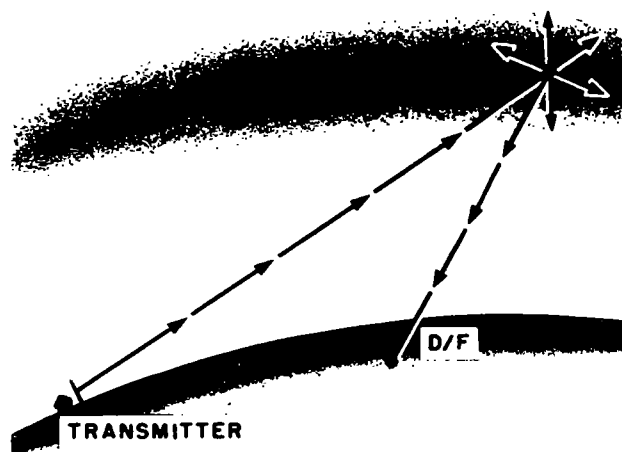


Figure 5-12. Short scatter.

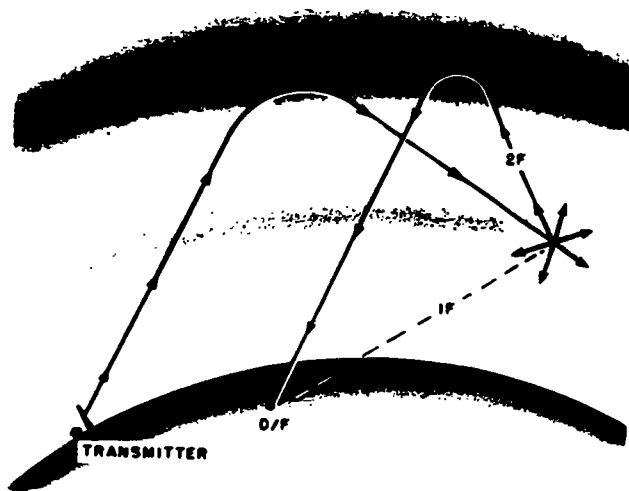


Figure 5-13. Long scatter.

radiated from the scattered source rather than from the transmitter itself.

b. Refraction. Radio waves, being electromagnetic in character, are bent or refracted from their normal path when they pass from one medium to another. A small

difference in the conductivity of the surface over which the wave is propagated or a change in the dielectric constant of the medium is sufficient to give rise to refraction. For example, the velocity of a radio wave over sea water is greater than its velocity over land. As a result, when a radio wave crosses a coast line at an oblique angle, its direction is appreciably altered (Capital A, fig. 5-15). The effect is particularly pronounced when either the DF site or the transmitting station is near the coast, especially if high ground intervenes. This effect also varies with the frequency of the wave.

c. Reflection. Incorrect azimuth readings are frequently obtained under conditions which suggest that reflection may sometimes be a contributing cause. Quite large and otherwise unaccountable errors are sometimes produced when a radio wave travels over or close to high cliffs, mountains, or buildings in its path to the direction finder (Capital B, fig. 5-15). Occasionally, conducting strata below the surface of the earth behave in the same manner as surface obstructions by reflecting the wave and causing errors. Generally, errors due to reflection are greatest when the reflecting mediums are in the vicinity of either the transmitter or DF set.

d. Reradiation. This effect occurs primarily as a result of the reradiation of the radio wave by metallic objects that are resonant at the frequency of the received wave. Even when the frequency of these objects is not resonant with the received waves, some reradiation may occur. The flux of such a reradiated wave will have a purely random phase with respect to the flux of the main wave. As a result, there will be a field composed partly of the strong main field and partly of the reradiated fields near the DF receiver, with different phase relations and polarization. These fields may combine to broaden the null, making the azimuth reading

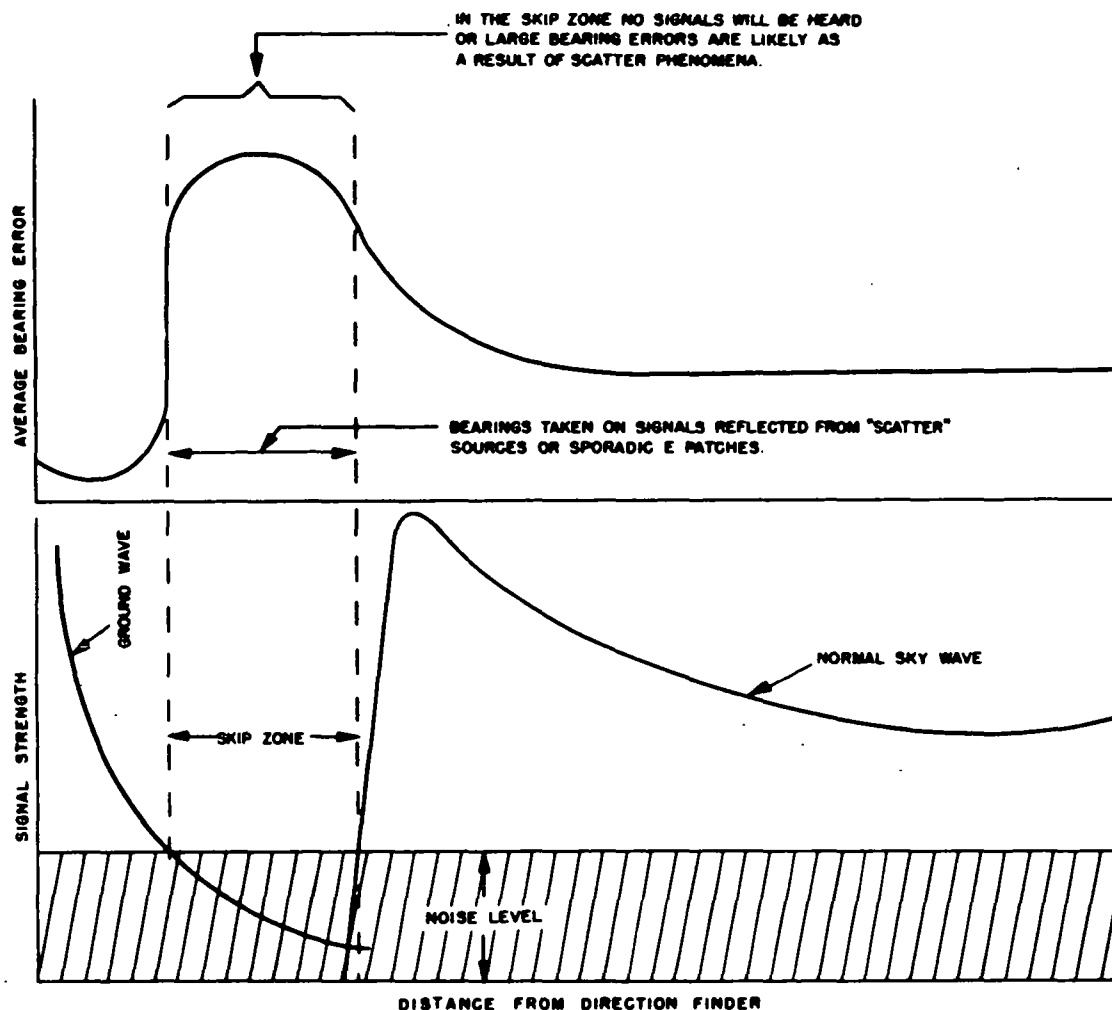


Figure 5-14. Effects of skip zone reception on bearing error.

indefinite and difficult to determine exactly. They also may combine to shift the null, causing error. Reradiation effects usually occur when the reradiating object is in the immediate vicinity of the DF site, although under some conditions, it may occur when the object is at a distance.

e. Methods of Reducing Path Error.

There is no practical method of reducing path errors originating from scatter, refraction, reflection, or reradiation. An exception to this can be made when the errors are due to the refraction, reflection, or reradiation of the radio wave in the immediate proximity of the DF site. In this case, the source of error may be removed, its effect adjusted by calibration, or the DF set moved to a more favorable

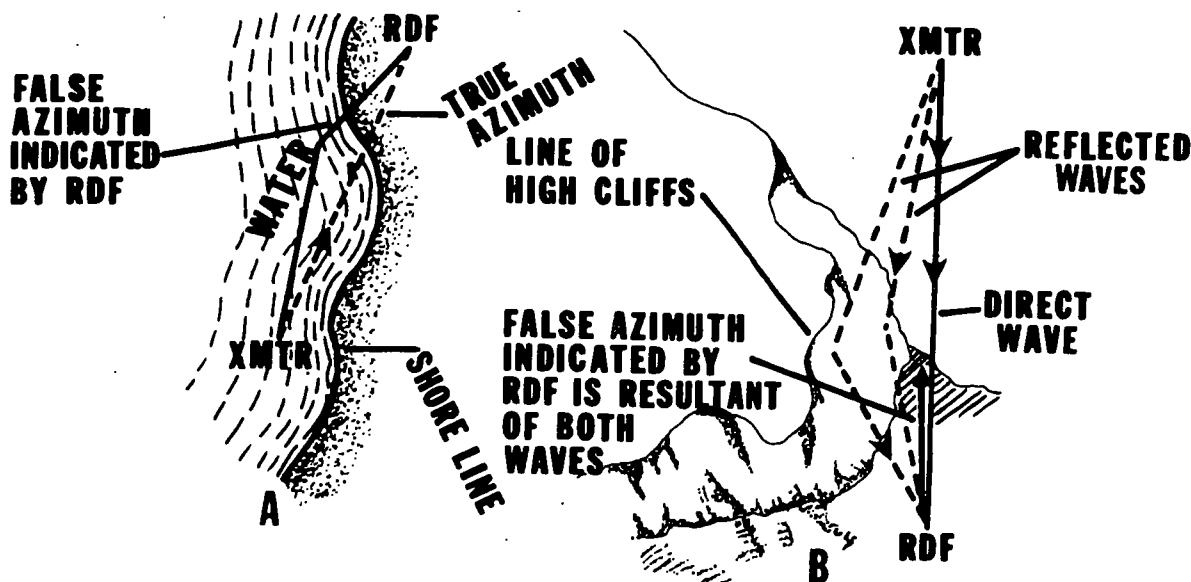


Figure 5-15. Error caused by the refraction and reflection of a radio wave.

location. Calibration for path errors, a considerable distance from the DF set is usually not possible.

5-18. Polarization Error.

Polarization error occurs when the undesired component of a radio wave induces voltage in a DF antenna.

a. Effects. This voltage tends to blur the bearing, making the azimuth reading indefinite and difficult to determine. For example, vertical loop and Adcock antennas are designed to receive vertically polarized waves. If the wave is abnormally or randomly polarized (contains both vertically and horizontally polarized components), the voltage induced by the two components may combine to produce the effect mentioned above. The magnitude of the effect will depend upon the ability of the loop or

Adcock to discriminate between the desired component (vertically polarized) and the undesired component (horizontally polarized) of the received signal. Other types of antenna systems are designed to receive horizontally polarized waves. With these antennas, polarization errors occur when the vertically polarized components of the radio waves induce voltage. The ways in which radio waves with abnormal polarization originate are described in paragraph 3-5.

b. Methods of Reducing Polarization Error. The effect of polarization error can be reduced by using a direction finder that is relatively insensitive to incorrectly polarized waves. When randomly polarized waves are received, a direction finder using an Adcock antenna would have less polarization error than a loop set. Additionally, when receiving substantially horizontally polarized waves, a horizontally polarized DF antenna would be superior to a vertically polarized antenna.

5-19. Site Error.

This error occurs in the immediate vicinity of the DF site as a result of many factors, some of which were discussed earlier in this manual. Error is kept to a minimum when the DF equipment is located in the best possible site. Paragraph 5-10 and table 5-1 provide specific installation guidance to eliminate site error. Compensation and calibration are possible for site error, but only if the error is large and reasonably constant without regard to variations in frequency, azimuth, and time.

5-20. Instrument Error.

This error is introduced by the DF equipment itself. The amount of instrument error varies with the design, general condition, and adjustment of the DF equipment. Factors which may introduce instrument error are: low signal-to-noise ratio, antenna effects, and other facets of the equipment discussed in the technical manuals published for the users of the particular sets.

5-21. Operator Errors.

This type of error is self-explanatory. These errors are reduced to a minimum when the operators have sufficient training and experience in operating the specific DF equipment to which they are assigned. In addition, the operator must be alert at all times. When a fading signal is being received, or when the bearing is shifting, the operator must be able to obtain readings at those times when the signal is strongest or most stable. Under adverse conditions, an efficient operator will usually take several different readings and then determine the azimuth by averaging them.

Section IV

PLOTTING METHODS

5-22. Definitions.

a. Line Bearing. This is the angular measurement of the arrival of a radio wave in degrees from true north after the null is obtained. A line bearing is sometimes called an azimuth or a shot.

b. Cut. This is the point of intersection of two DF bearings.

c. Fix. This is the probable location of a target transmitter's antenna when three or more DF bearings have been plotted on a chart or map.

5-23. Plotting.

a. Plotting a Bearing. The simplest method of plotting a bearing is with a protractor and straight edge. Point A in figure 5-16 represents the known location (by grid coordinates) of a DF station. This is entered as a tick mark (.) on the map or overlay. The index of the protractor is placed to coincide with point A and is accurately aligned along the north-south grid lines by using dividers or parallel rulers. The bearing taken by the DF station is measured in degrees from true north and is indicated by another tick mark at the appropriate degree on the protractor. The protractor is removed and the straight edge aligned along the two tick marks. The bearing is then plotted by drawing a line along the straight edge from the station location through the degree tick mark, extending a sufficient length into the target area so that the enemy transmitter may reasonably be expected to be located along this line.

b. Plotting a Cut. Using the method outlined above, the bearing from a second DF station is plotted. The intersection of the two bearings thus plotted is identified as a DF cut (fig. 5-17).

c. Plotting a Fix. If three DF stations are arranged along a baseline, the protractor may still be used. DF stations A, B, and C are

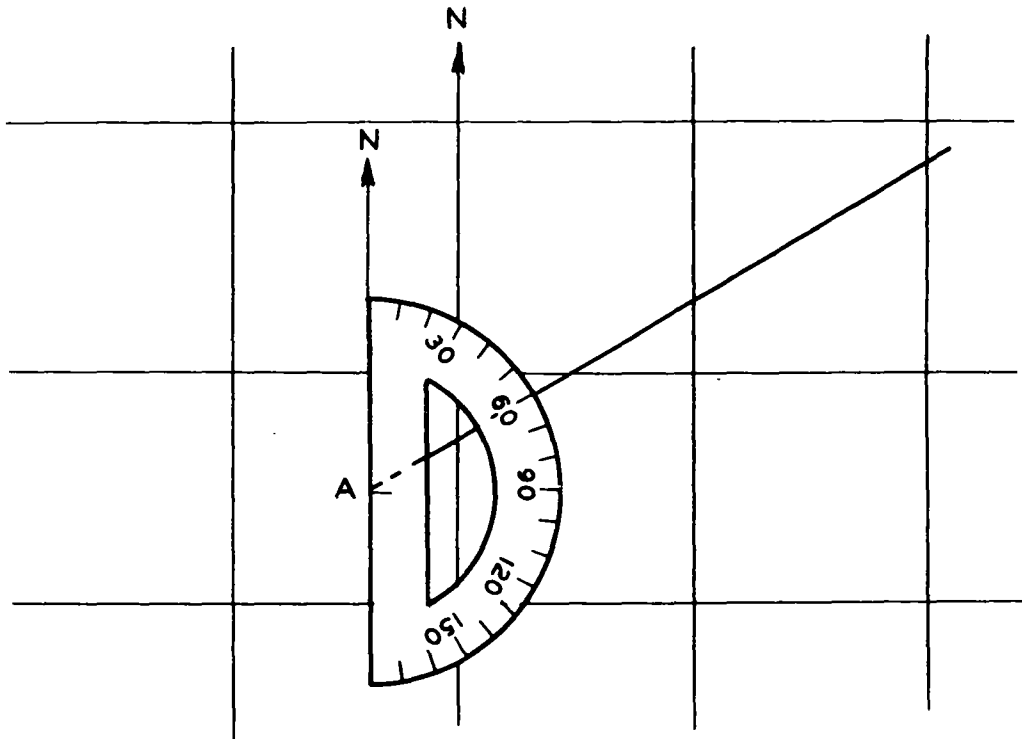


Figure 5-16. Plotting a bearing.

located as shown in figure 5-18, and have reported bearings of 132, 182, and 233 degrees respectively. Again the protractor and straight edge may be used to plot successively the bearings of each DF set at its map location; the lines may be extended to form a small triangle, or join at a point if the fix is perfect. A perfect DF is extremely rare, however, figure 5-18 illustrates a perfect fix.

d. Plotting Control and Evaluation Centers. The plotting procedures described above, while completely valid in terms of accuracy, are somewhat slow and laborious. With the advancement of DF and the greater number of bearings reported by individual stations, the plotter would find it difficult to plot all the DF results. Accordingly, DF plotting centers, with the capability of

analysis in depth, have been established. In such centers, plotting boards with the DF stations represented by strings which may be pulled out and lined on calibrated map-edge scales are used. The plotter simply notes the station, the reported bearing, and the calibrated edge scale for the particular reporting station. The compass rose around each DF station has been transferred to the map-edge scales mentioned above. When the string is pulled out and alined along the reported bearing on the map-edge scale, the bearing is plotted. Additional stations are also plotted, and the intersection of the bearings determines the probable target location. Evaluation of DF plotting will be discussed in greater depth in section V. Computerized plotting of DF results is possible in the SWDF nets dealing primarily with the strategic location of targets.

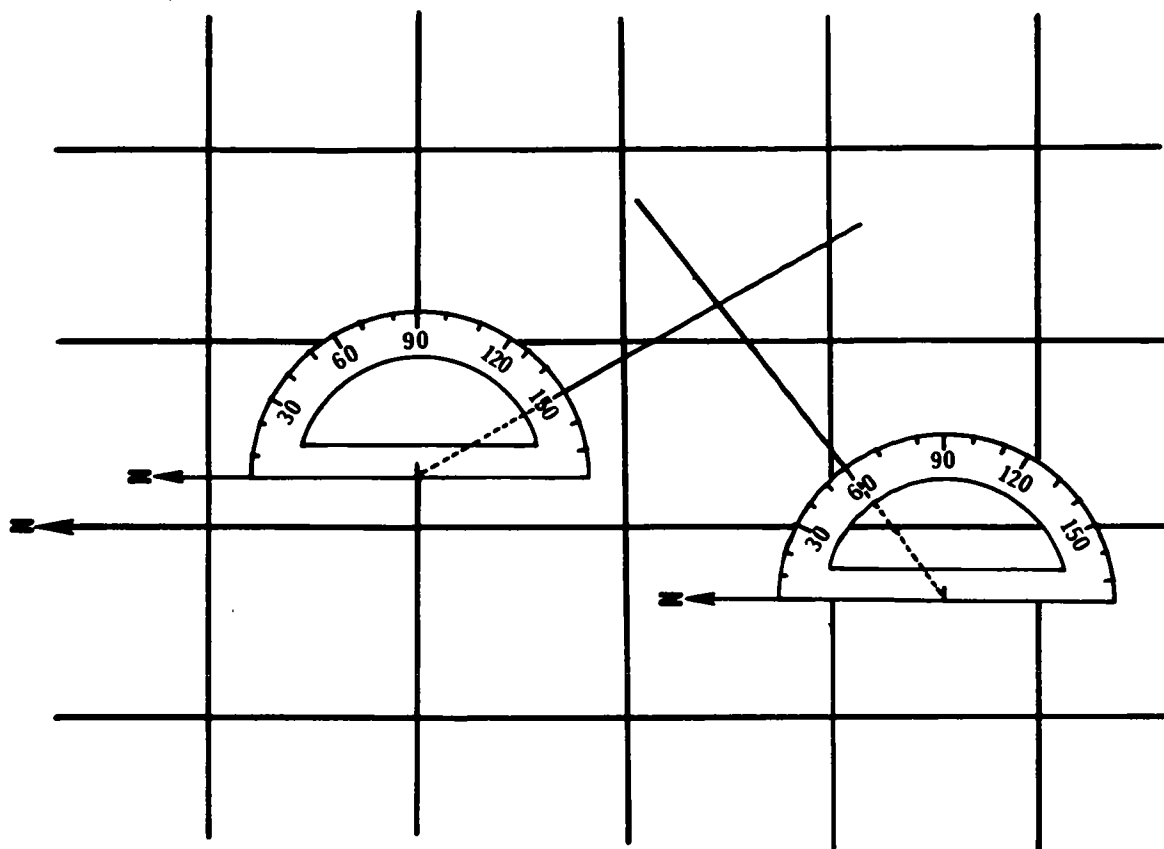


Figure 5-17. Plotting a cut.

5-24. Baselines.

The size and scale of the maps used in plotting will depend upon the range of bearings to be plotted and, of course, upon the length of the DF baseline. The baseline, in turn, is affected by the range of fixes to be obtained, and is limited by the terrain and the DF control net. The limit of an area in which the desired enemy targets will be expected to appear is not definite due to many variables, but experience will dictate the best layout for a given situation. A baseline, ideally, should be the same length as the expected depth of the target area. When these dimensions are observed, at least two of the DF stations will

be measuring arriving signals at nearly right angles which is the most desirable.

Section V

EVALUATION OF DF RESULTS

5-25. General.

In section IV, plotting was discussed in general terms with several illustrations given representing near-perfect conditions. In the practical application of DF plotting, the returned bearings are carefully evaluated by the plotters to determine the most nearly correct location of the target of interest. A perfect fix, with three or more bearings

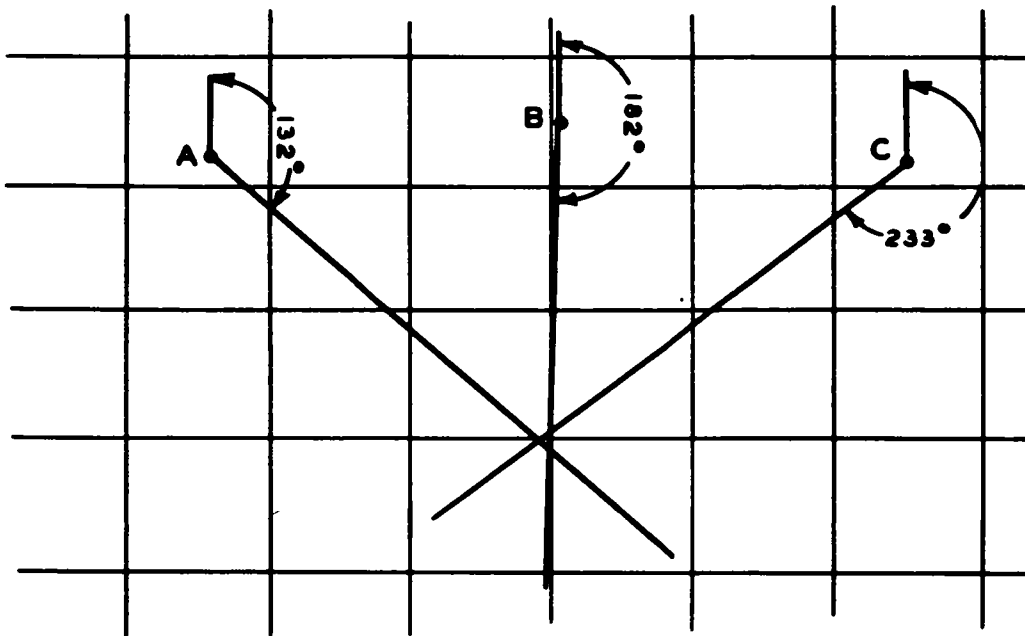


Figure 5-18. Plotting a perfect DF fix.

intersecting at an exact grid location, is so rare it is almost unknown. The plotter has many factors which he must resolve.

5-26. Evaluation by the DF Operator.

Initially, the bearing is obtained by the operator at the DF site and reported to the plotting center or control. The operator's experience, judgement, operating skills, and ability to read the bearings, are factors which affect the accuracy of the reported bearing. A system of evaluating the reliability of a bearing does exist; however, the specific details cannot be discussed within the classification limitations of this manual. Very basically, the operator affixes a designator which reflects a degree of confidence in target identification and a measure of signal conditions at the time the bearing was obtained.

5-27. Evaluation by the Plotter.

A DF plotter is substantially influenced by several human factors in his evaluation of bearings reported from the DF stations in his net. As his experience builds, and reported fix locations are confirmed by enemy contacts and other irrefutable means, the plotter will grant increasing credibility to one DF site over another. Known site error itself will, on many occasions, cause the plotter to reject, or accept on reduced reliability, bearings from certain stations. A change of operating personnel at a particular site, if known to the plotter, may also influence his decision on the reliability to assign a reported bearing. In spite of the standard assignment of reliability indicators, plotting is still very much influenced by these human factors.

Section VI

DETERMINATION OF FIX AREA

5-28. Methods Used to Determine Probable Target Locations.

DF fixes illustrated previously have been "perfect" with all bearings intersecting at an exact grid location. Of course, such a fix seldom occurs because of the inherent errors in DF operations. The continually changing electromagnetic environment of each DF site and the errors discussed previously contribute to these inherent errors. Consequently, fixes obtained after plotting three bearings may appear on the plotting map as indicated in figure 5-19. It is readily apparent that the triangle formed by the three plotted bearings could cover a substantial portion of the tactical area; therefore, methods had to be established to evaluate the most probable location of the target in the triangle. Some of the methods used are the bisection of the medians (sides) of a triangle, bisection of the angles of a triangle, and the Steiner point method. Of these three, the Steiner point method is the most commonly accepted, especially for tactical use. As illustrated in figure 5-20, there is little difference in the three solutions. Strategic DF nets will most

often use the visual inspection method, but prior to using this method, a reliable data base must be established.

a. *Bisection of the Medians of a Triangle.* Evaluating a fix using this method, the plotter must draw a line from the midpoint of each median to the opposing angle. As shown in figure 5-20, a line is plotted from the midpoint of line AB to angle C, another from midpoint of line BC to angle A, and the last line from the midpoint of line AC to angle B. The error triangle solution or probable target emitter location is the point where the three lines intersect (A^1).

b. *Bisection of the Angles of a Triangle.* Determining the error triangle solution by bisecting the angles of the triangle is shown in figure 5-20. First, the plotter must determine the degree of each angle, then each angle must be bisected. In figure 5-20, the bisecting lines are drawn from angle A to point 1, from angle B to point 2, and last, from angle C to point 3. The solution (B^1) is the point where three lines intersect.

c. *Steiner Point.* The Steiner point method of determining the location of the target within the error triangle is probably the easiest and most accurate once a template is constructed. Draw a large circle on a sheet of clear plastic and drill a small hole in the exact center. Three lines are etched from the center to the outside of the circle exactly 120 degrees apart, thus trisecting the circle. Lay this template over the error triangle formed after the three bearings are plotted, rotate and maneuver it until each of the 120 degree lines is over the corners of the error triangle. Mark the location (C^1) with a pencil through the hole in the center of the template (fig. 5-20). This mark is reported, by grid coordinates, as the probable target location.

d. *Visual Inspection.* The visual inspection method of fix evaluation

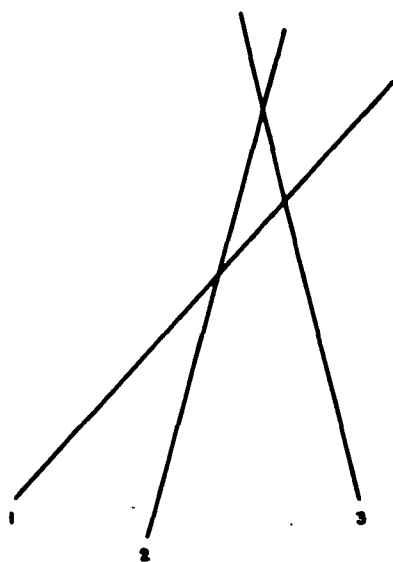
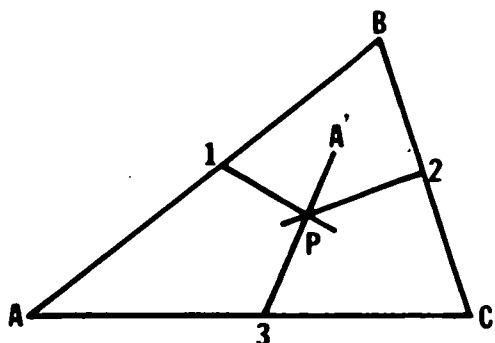
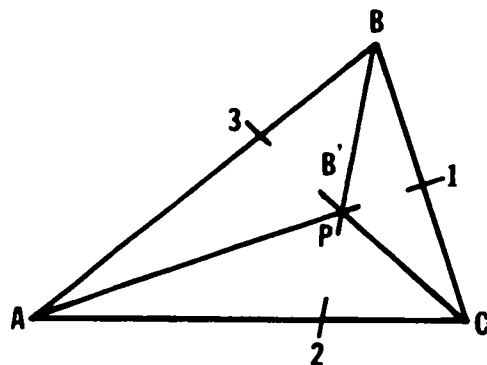
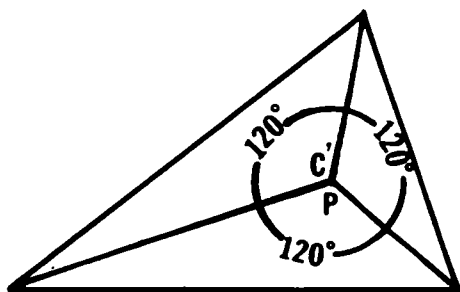
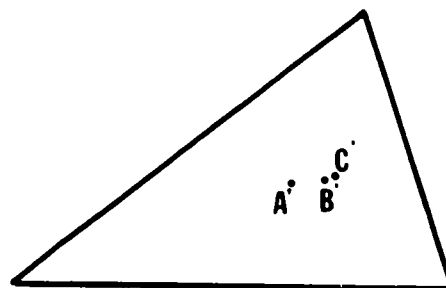


Figure 5-19. Three-station fix, error triangle.

**A. BISECTING THE MEDIANS****B. BISECTING THE ANGLES****C. STEINER POINT****D. THE SOLUTIONS***Figure 5-20. Error triangle solution.*

encompasses several factors relating to the reported bearings. Paragraph 5-26 described how the operator assigns a classification or evaluation to the bearing. This factor is blended with the known reliability of the DF site based upon past performance. The distance that a radio wave travels before reaching the DF site as well as the terrain features around the DF site are also considered in the visual inspection method of fixing the probable location of a target

emitter. Angles that intersect at or near right angles are desirable and weigh heavily in producing the probable location of a target. As illustrated in figure 5-21, if the angle from point A is increased by 10 degrees, the area of increase is greater than that produced when the angle of point B is increased by 10 degrees. This is the reason angles near 90 degrees are desirable. To better illustrate visual inspection, the original bearings from four DF stations, have been plotted (figure

5-22). The obvious error triangle is the one formed by lines plotted from bearings reported from stations 1, 2, and 4. However, the analyst in the plotting center knows that stations 1 and 2 have a huge body of water between them and the target area. From the data base, he knows that DF stations 1 and 2 have a plus 10 degrees bearing error for this particular frequency and angle. Using these known facts, the experienced plotter subtracts 10 degrees from the reported bearings of stations 1 and 2. The error triangle with the adjusted bearings is now located in a different and much smaller area formed by lines plotted from stations 1, 2, and 3 as shown in figure 5-22. The analyst has also determined that station 4 reported a bearing for a similar but different signal.

5-29. Deductions Relating to Probable Target Locations.

By using these methods to produce a probable target location, the plotter must examine the

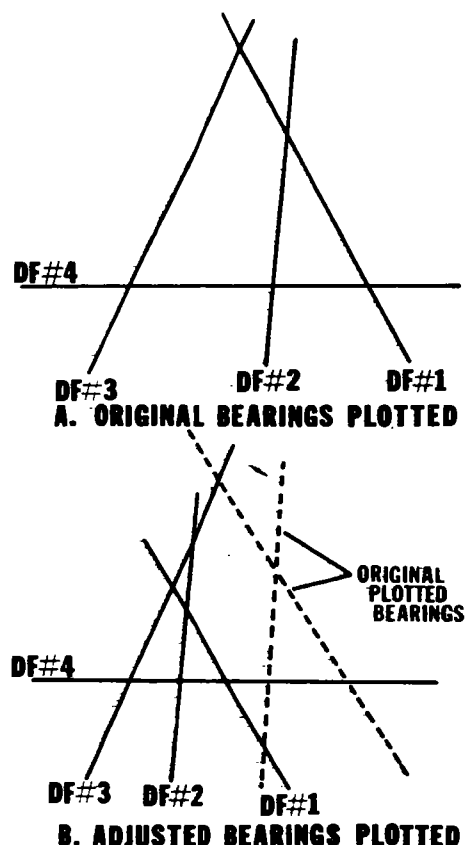


Figure 5-22. Plotting using reported bearings and data base.

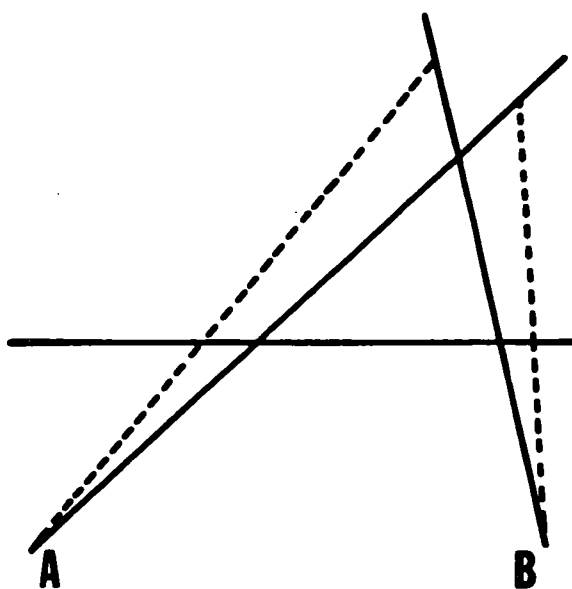


Figure 5-21. Angle increase comparison.

map in detail and study the geographical qualities of the fixes that have been produced. Should the location be indicated as the middle of a large lake, there is little likelihood that the transmitter would be accurately located if the target were serving a large headquarters. On the other hand; however, if the target is a low-powered, clandestine station about which little is known, and the fix is made during the hours of darkness, it may very well be accurate; e.g., a man-portable transmitter operating in a boat crossing the lake. If the fix point is located atop an inaccessible crag or butte, the plotter must once again apply a little logic and examine the terrain features adjacent to the indicated location. Transmitters usually serve a command or headquarters and are likely to be located where such troop units would logically be stationed or encamped. Camps,

trails, roads, water supplies, and similar terrain features must be evaluated in the formation of fix location.

5-30. Plotting with Four or More Bearings.

a. In larger plotting centers serving many outstations, several bearings may be received on the same target, requiring plotting from more than three bearings. The evaluative process mentioned above still applies. Ultimately, however, the plotter is confronted with a probable location triangle, quadrilateral, or other geometric figure formed by the plotted bearings. The details of these solutions are beyond the scope of this manual.

5-31. Mechanization of DF Plotting.

These methods of plotting to determine a fix point or fix area are predicated on the assumption that the plotting is done on a map board with a protractor and ruler at each DF site, or a string board on which the DF stations have been geographically located. Systematic errors and standard deviation have been interpolated according to all DF stations represented on the plotting board, and the map-edge scale is, therefore, accurate to that station's reported bearings. With the introduction of lightweight, portable computers rugged enough to withstand the exposures of field deployment, DF bearings reported in certain nets are translated into computer language, and determination of the fix areas or fix point is done electromechanically. The least square method of plotting is the basis for all computer plotting, however, because of its complexity, it is beyond the scope of this manual.

CHAPTER 6

Tasking and Reporting

Section I

COMMUNICATIONS REQUIREMENTS FOR DF NETS

6-1. Methods of Communications Within DF Nets.

The methods of communications used by DF nets are landline teletypewriter, radio teletypewriter, CW, and radiotelephone. All of these methods of communications must be secured with cryptosystems. A prime consideration of a DF net is the security and speed with which its users may effectively communicate.

a. The primary method of communications for strategic DF is secure, online teletypewriter using the Defense Special Security Communication System (DSSCS).

b. Methods of communications for tactical DF are CW, secured radio teletypewriter, and radiotelephone.

6-2. Problems of Control.

From the simplest to the most complex DF nets, there are certain functions which must be performed from the time a bearing is requested until the resultant bearings are obtained and the estimated target location is reported. These functions, in a reasonably chronological sequence, are:

a. The bearing to or position of a target station is required for intelligence purposes

(mission authorized action). Sufficient information concerning callsigns, frequency, and type of traffic passed must be furnished to permit identification of the target signal. This information is usually obtained from an intercept-search mission which identifies new stations of interest or substantiates the continuance of old stations with an interest in determining possible displacement. The completeness of this information is not always predictable. Generally, however, the DF operator does not spend his time searching the frequency bands for targets.

b. The mission, with all available information on the operation of the target station or net, is given to the radio intercept operator who searches for the desired signal and copies it to obtain traffic and keep the DF controller informed of the station's or net's activities.

c. As soon as the desired station or net is active, the radio intercept operator notifies the DF controller. He also provides the controller with any identifying details not already known.

d. The DF controller notifies all DF operators of the station's or net's activities, callsigns, frequencies, and other identifying information. This takes place over the flash net.

e. Bearings obtained by the DF operator are reported to net control. The reported bearings are plotted and the probable target location given to the commander who authorized or requested the mission. The assignment of the mission to the DF operator and the reporting of the results is accomplished by any of the means of communications mentioned above. If a DF

station happens to be colocated with the intercept facility, communication between the DF controller and the operator is within the confines of the facility, and requires none of the above. When only one DF set is used, only a line bearing can be obtained. In this situation, the commander desiring the bearing is usually in close proximity to the supporting DF site, and requests are made in person, with the results rendered in the same way. This single site DF effort is usually for close tactical support when a ground commander wishes to confirm his contacts or suspicions about the enemy's location. After the initial mission has been assigned to the operator, the controller can employ certain codes (if equipped with online cipher devices) or speak directly to the operator (if speech privacy equipment is available) to keep him informed as to exactly what the target station is doing. This is called "tracking" the station, and is used to ensure positive identification by the operator. Various DF missions will be assigned priorities depending upon the urgency of the tactical situation or the overall intelligence effort. When the missions terminate, the results are forwarded to control over a second net, called the reporting net.

Section II

TASKING AUTHORITY AND COMMAND STRUCTURE OF DF NETS

6-3. General.

Tasking, or mission assignment, is extremely complex, ranging from the tactical commander's request to requirements generated at the national level. A discussion of the detailed generation of missions is not within the scope of this manual. Such information may be obtained, if required, from the liaison officer assigned at each level of command who acts as a resources manager for the units providing DF support.

6-4. Basic Net Requirements for DF Support.

Without regard for the means of communications employed, a DF net requires communications circuits as shown in figure 6-1. The flash net, over which missions are assigned, is indicated by the solid lines, while the reporting net over which mission results are passed, is indicated by the broken lines. This is the basic communications requirement for any DF net. Tracking is conducted over the flash net after the missions are assigned. All bearings are returned over the reporting net.

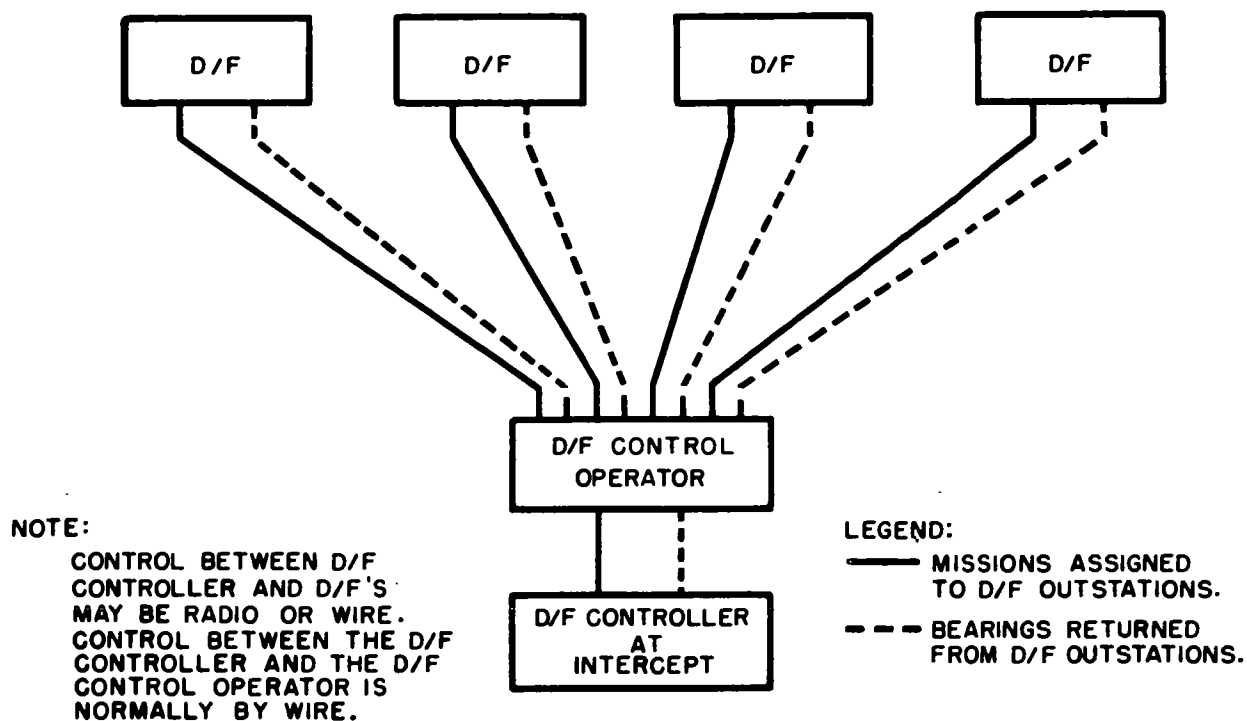


Figure 6-1. DF net control arrangement.

CHAPTER 7

Direction-Finding Computations

Section I

GNOMONIC PROJECTION CORRECTION TECHNIQUES

7-1. General.

The gnomonic projection is the most common map used for long-range DF plotting. Its primary characteristic is the appearance of all great circles as straight lines. Distortion on the gnomonic is minimum at the point of tangency but increases as the distance from the point of tangency increases. For example, the boundaries near the edge of the projection are badly distorted and are practically useless for determining true shapes and distances. This distortion does not affect plotting activities if the DF equipment is located within a four degree radius from the point of map tangency, and bearings can be plotted to any point on the chart without any appreciable error. However, if the DF station is located outside the four degree radius, angular correction must be applied before its bearings can be accurately plotted. The computation methods used to correct this distortion are border coordinates and the corrected compass rose (CCR).

7-2. Border Coordinates.

Border coordinates not only correct angular distortion on a gnomonic chart, but provide what is perhaps considered the most accurate method of plotting DF bearings. Border coordinates divide the perimeter of the gnomonic chart into 1,000 equal spaces,

which are denoted by tick marks. Every tenth mark is numbered, starting with 00 at the upper left-hand corner and continuing clockwise to 100. The border coordinates are constructed on the chart so that 00 through 30 are located on the top border; 30 through 50 are located on the right border; 50 through 80 are on the bottom border; and 80 through 100 are located on the left border. The spaces between the tick marks can be mechanically interpolated into tenths, providing a total of 10,000 coordinates for plotting purposes. Tables are constructed for each DF site, providing coordinates for all azimuths. When a bearing is reported by a DF site it is converted to border coordinates and plotted on the gnomonic chart by drawing a line between the coordinate and the DF site. Border coordinates and conversion tables are machine computed and may be obtained on request to higher headquarters. The applicable gnomonic chart number and the exact latitude and longitude of each DF site location must be included in the request.

7-3. Corrected Compass Rose.

a. General. The corrected compass rose is nothing more than a compass rose which has been corrected or expanded to compensate for angular distortion. In other words, the degree marks have been placed closer together or moved farther apart, according to the amount of distortion present. When situated on the gnomonic plotting chart the CCR must have its center exactly over the direction-finding site location. Bearings can then be plotted from the CCR or the rose can be extended to a line around the edge of the map in the same manner as border coordinates.

b. Right-Triangle Method. Constructing a corrected compass rose by the right-triangle

method entails the computation of mathematical formulas and is time consuming; however, this is compensated by the high degree of accuracy and reliability it provides. Since radio waves follow great circle paths, the right-triangle method of error correction is concerned with spherical trigonometry. Under theoretical conditions, the equator and the selected meridian would intersect at a right angle (fig. 7-1). The azimuth from the direction-finding site would intersect both the equator and the selected meridian forming a right triangle. A common logarithm of functions of angles in degrees and minutes table (appendix B) is used to solve the unknown quantities of a spherical right triangle. For additional information on the principles and application of logarithms, reference TM 11-684.

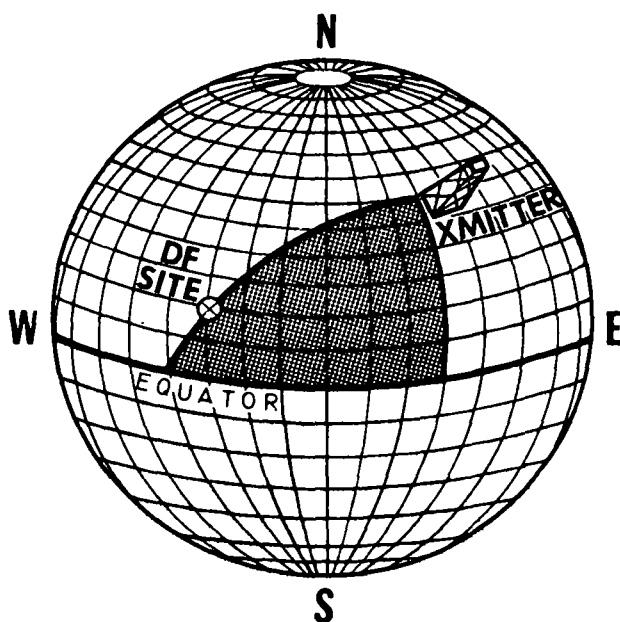


Figure 7-1. Spherical right triangle.

(1) The three known factors of the computation are:

(a) The latitude and longitude of the DF site.

(b) The longitude of the selected meridian.

(c) The desired azimuth.

(2) The selected meridian used during the computation should be in the approximate center of the area of interest. It also should be noted that one single meridian need not be used for the computation of the entire CCR.

(3) Figure 7-2 illustrates the formula used in the right-triangle method of computation.

(a) The bottom line marked 0 degrees represents the equator.

(b) Line a is the distance in degrees and minutes from the equator to the DF site, or the latitude of the site.

(c) Angle B is the desired azimuth which is to be corrected for angular map distortion.

(d) Angle A is the angle the desired azimuth makes at the equator. Note that angles A and B do not total 90 degrees as in a true right triangle because the right-triangle method deals with a right triangle only in theory and the functions are computed by spherical trigonometry.

(e) Line b is the distance in degrees and minutes of the difference in longitude between the DF site and the intersection of the azimuth with the equator.

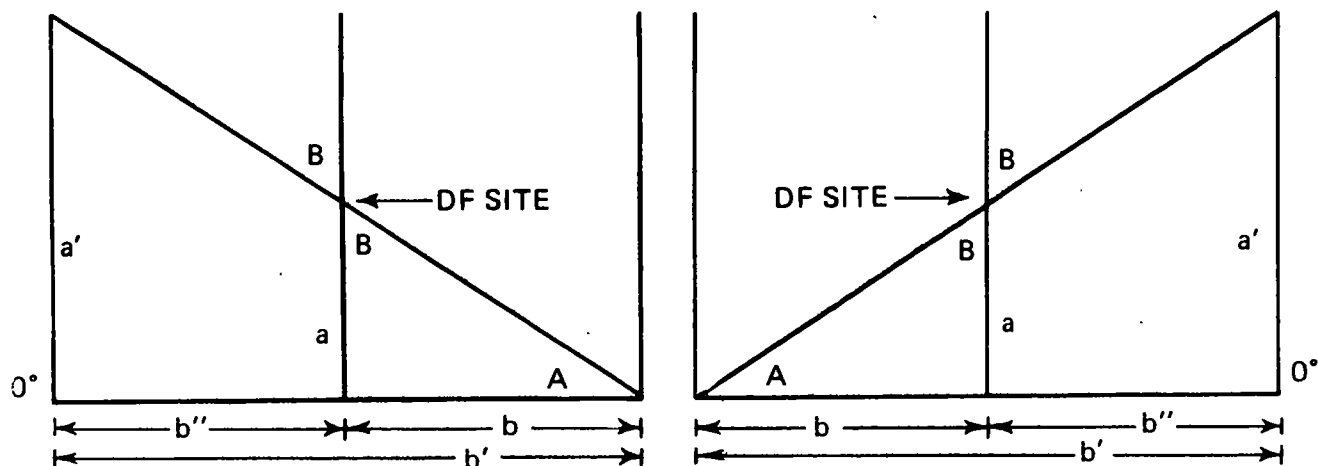
(f) Line b'' is the distance in degrees and minutes from the DF site to the selected meridian.

(g) Line b' is the difference in longitude of the intersection of the azimuth with the equator and the selected meridian. Or, line b' is the sum of lines b and b''.

(h) The value of a' represents the latitude at which the bearing will intersect the selected meridian.

c. Common Logarithms of Functions of Angles in Degrees and Minutes Table.

(1) Degrees. Each page of the appendix B table is computed for eight



B= _____ a= _____ b''= _____ b= _____

a'= _____ A= _____ b'= _____

$$(\log \tan b) = (\log \sin a) - (\log \cot B)$$

log sin a: _____

log cot B: _____

Diff: _____ = log tan b

b= _____

$$(\log \cos A) = (\log \cos a) + (\log \sin B)$$

log cos a: _____

log sin B: _____

Sum: _____ = log cos A

A= _____

$$(\log \tan a') = (\log \sin b') - (\log \cot A)$$

log sin b': _____

log cot A: _____

Diff: _____ = log tan a'

a'= _____

Figure 7-2. Right triangle computation worksheet.

different angles, of which four are indicated in the upper left-hand corner and four in the lower right-hand corner. The fact that one page is sufficient for the functions of eight different angles is a result of the properties of trigonometric functions. For example, the sine of 0 degrees is numerically equal to the sine of 180 degrees and the cosine of 90 degrees is equal to the cosine of 270 degrees.

(2) *Minutes.* The minutes for each angle are found in the columns headed by the mathematical sign for minutes ('). The minutes for the angles in the upper left-hand corner are read *down* the left minute column. The minutes for the angles in the lower right-hand corner are read *up* the right minute column.

(3) *Use of the tables.*

(a) To determine the logarithm of an angle:

1. Locate the page containing the angle of the trigonometric function.

2. Follow the angle's minute column up or down, as required, until the exact minute reading is located.

3. Determine which function is appropriate by consulting the legend either at the top or the bottom of the table. Angle functions are *opposite* each angle or degree reading. The number found at the intersection of the function column and the logarithm row opposite the minute column is the logarithm of that angle.

(b) To determine the angle of a logarithm:

1. Locate the logarithm which is *nearest* the given logarithm in the appropriate function column.

2. The minute value will be selected from either the corresponding number in the left minute column or the right minute column.

3. Note the corresponding angles of the function column, top left-hand corner and bottom right-hand corner, and select the *lowest* of the four angles. If the

selected angle is at the top of the page, read the minute value from the left minute column. However, if the selected angle is taken from the bottom of the page, read the minute value from the right minute column.

d. *Right-Triangle Method Example.* The desired azimuth or angle B which is to be corrected for angular distortion is 10 degrees. The latitude of the DF site or line a is 36 degrees. The difference in longitude between the DF site and the selected meridian, or b'' , is 5 degrees. (Reference appendix B for logarithm table.)

Step 1. Find b:

$$\begin{aligned}(\log \sin a) - (\log \cot B) &= (\log \tan b) \\ \log \sin 36^\circ &= 9.76922-10 \\ \log \cot 10^\circ &= \underline{0.75368} \\ \log \text{diff} &= 9.01554-10 \\ \log \tan b &= 9.01554-10 \\ b &= 5^\circ 55'\end{aligned}$$

Note. Always select the *lowest* degree and minute reading.

Step 2. Find b' :

$$\begin{aligned}(b'') + (b) &= (b') \\ b'' &= 5^\circ \\ b &= \underline{5^\circ 55'} \\ b' &= 10^\circ 55'\end{aligned}$$

Step 3. Find A:

$$\begin{aligned}(\log \cos a) + (\log \sin B) &= (\log \cos A) \\ \log \cos 36^\circ &= 9.90796-10 \\ \log \sin 10^\circ &= \underline{9.23967-10} \\ \log \text{sum} &= 19.14763-20 \\ \log \cos A &= 9.14763-10 \\ A &= 81^\circ 55'\end{aligned}$$

Step 4. Find a' :

$$\begin{aligned}(\log \sin b') - (\log \cot A) &= (\log \tan a') \\ \log \sin 10^\circ 55' &= 9.27734-10 \\ \log \cot 81^\circ 55' &= \underline{9.15236-10} \\ \log \text{diff} &= 0.12498 \\ \log \tan a' &= 0.12498 \\ a' &= 53^\circ 08'\end{aligned}$$

Step 5. A straightedge aligned with 53 degrees and 8 minutes latitude on the selected meridian will indicate the corrected azimuth for 10 degrees. When

constructing a corrected compass rose a tick mark should be placed on the compass rose and numbered 10 degrees, or a tick mark placed on the edge of the plotting chart and numbered 10 degrees.

(1) It is apparent that logarithm tables are constructed in such a manner so that the area from 0 to 90 degrees will represent the entire 360 degree circle. Any computation using X degrees east as the selected meridian will also be correct for X degrees west and both reciprocals. Therefore, any single computation will yield four azimuths; 90 computations are required to complete the entire compass rose.

(2) A problem area may arise when computing desired azimuths around 90 or 270 degrees. To eliminate confusion, subtract the value of (b) from 90 degrees and complete the computations normally. This procedure should also be used approximately 5 degrees on either side of the 90 or 270 degree azimuth which will ensure standard accuracy.

Section II

GREAT CIRCLE AZIMUTHS

7-4. General.

Radio waves follow great circle paths between the transmitting and receiving antennas. When the exact location of the signal source is known, it is possible to compute the true or great circle azimuth and distance (GCAD) from the point of signal origin to any other point receiving the signal on the surface of the earth. The computations of great circle azimuths are based on spherical trigonometry and may be computed using the dead reckoning altitude and azimuth table in appendix C. This method is simpler and much faster than using other logarithmic methods and is accurate to within one-half a minute. Greater accuracy is possible by interpolating between table functions.

7-5. Dead Reckoning Altitude and Azimuth Table.

The dead reckoning altitude and azimuth table is arranged in parallel "A" and "B" columns. The "A" columns contain log cosecants multiplied by 100,000 and the "B" columns contain log secants multiplied by 100,000. The "A" columns decrease in value from the front of the table toward the rear, while the "B" columns increase in value from the front of the table to the rear. When determining degrees and minutes from the top of the table, read the minutes from the *left-hand* column. However, when reading the degrees and minutes from the bottom of the table, read the minutes from the *right-hand* column. It should also be noted that if the desired degrees and minutes exceed 180 degrees, it is necessary to subtract 180 degrees before entering the table.

7-6. Great Circle Azimuth and Distance Computation.

a. General. Great circle azimuth and distance computations are based on spherical trigonometry. A terrestrial triangle has curved sides and is commonly referred to as a spherical triangle. Refer to figure 7-3 and you will see that the shaded portion of the illustration is a spherical triangle. The determination of the true azimuth and distance is reduced to simply completing the worksheet (fig. 7-4) using the dead reckoning altitude and azimuth table.

b. Formula symbols. The following symbols are used in the GCAD formula (fig. 7-3):

(1) L or lat is the latitude of the initial position or the DF site.

(2) L' or lat' is the latitude of the final position or the check station.

(3) $\angle B$ is the great circle azimuth from the check station to the DF site.

(4) D arc is the great circle distance, in minutes of arc, between the target and the DF site. (One minute of arc equals one nautical mile.)

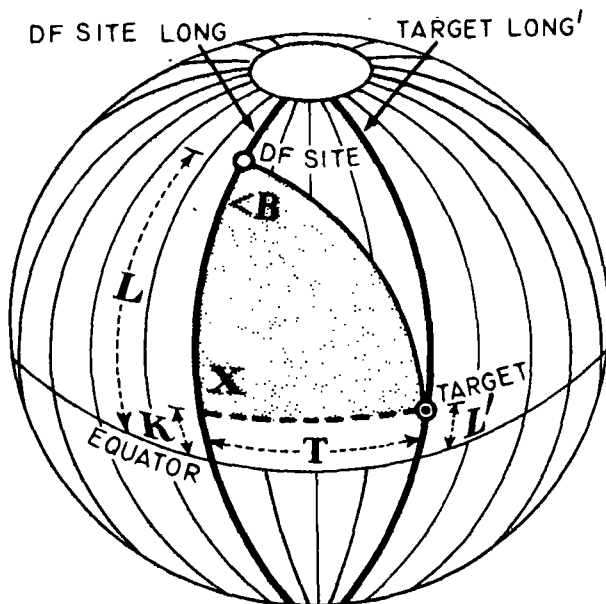
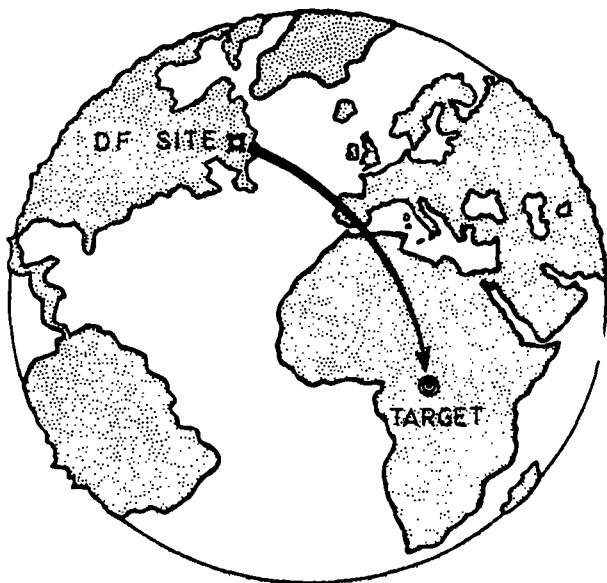


Figure 7-3. Spherical triangle.

(5) X is a factor introduced to simplify the computation and represents that point at which a great circle constructed perpendicular to the target's meridian crosses the meridian of the DF site.

(6) K is the latitude of point X or the arc from X to the equator (assumes the name of the latitude of the final position.)

(7) KL is the difference between K and L .

(8) $Long$ is the longitude of the DF site.

(9) $Long'$ is the longitude of the check station.

c. Special Rules. The fact that D arc may be greater than 90 degrees has necessitated the following rules.

(1) *Rule 1.* When L and L' are the same name (north or south) the following procedures are applicable.

(a) When T is *greater* than 90 degrees, select the K value from the bottom of the table. When T is *less* than 90 degrees, select the K value from the top of the table.

(b) Record $\angle B$ from the top of the table when K is *greater* than L . When K is *less* than L select $\angle B$ from the bottom of the table.

(c) D arc is recorded from the top of the table *except* when T and KL are *both greater* than 90 degrees.

(2) *Rule 2.* When L and L' are different names the following procedures are applicable.

(a) When T is *greater* than 90 degrees select the K value from the bottom of the table. When T is *less* than 90 degrees select the K value from the top of the table.

(b) Record $\angle B$ from the bottom of the table *except* when KL is *greater* than 180 degrees.

(c) D arc is recorded from the bottom of the table *except* when T and KL are *both less* than 90 degrees.

(d) When KL exceeds 180 degrees, subtract 180 degrees before making a table computation.

(3) *Rule 3. Computation of $\angle B$.*

(a) When the initial position is in the *Northern Hemisphere* and is *west* of the final position, $\angle B$ is the true bearing. If the initial position is *east* of the final position, $\angle B$ is subtracted from 360 degrees to obtain the true bearing.

(b) When the initial position is in the *Southern Hemisphere* and is *west* of the final position, subtract $\angle B$ from 180 degrees. If the initial position is *east* of the final position, add 180 degrees to $\angle B$ to obtain the true bearing.

d. *GCAD Worksheet.* To facilitate the computation process, a GCAD worksheet is illustrated in figure 7-4. It is divided into a heading and the step-by-step procedure for determining true azimuth and distance. An explanation of the worksheet and the GCAD formula follows.

(1) The heading contains the latitude and longitude of the direction-finding site and the selected check station. The following abbreviations are used:

(a) FROM: The name of the DF site.

(b) LAT or L: The latitude of the DF site.

(c) LONG: The longitude of the DF site.

(d) TO: The name of the target station.

(e) LAT' or L': The latitude of the target station.

(f) LONG': The longitude of the target station.

(g) To determine T, the following procedures should be followed:

1. If LONG and LONG' are in the same hemisphere, (same names) *subtract* to determine the T value.

2. If LONG and LONG' are in different hemispheres, (different names) *add* to determine the T value.

(2) The remainder of the worksheet is divided into the DEGREES/MINUTES

column and COL-1 through COL-4. The mathematical function is indicated at the top of each column. Logarithms are entered at the spaces "A" and "B" beginning with COL-1 and the appropriate function performed. If other logarithm tables are used instead of the dead reckoning altitude and azimuth table, column A will equate to the log cosecant and column B will equate to the log secant. Prior to beginning the computation, enter the T value in the appropriate space under the DEGREES/MINUTES column.

e. *Computation Procedures.*(1) *COL-1.*

(a) Locate the T value in the dead reckoning altitude and azimuth table (appendix C). Enter the figure found under the corresponding A column in the appropriate space under COL-1.

(b) Enter L' in the appropriate space under the DEGREES/MINUTES column.

(c) Locate the L' value in the table. Enter the corresponding B column number in the appropriate space under COL-1.

(d) Add the COL-1 A and B values. Enter the result under the final A space in COL-1.

(2) *COL-2.*

(a) Locate the L' value in the table. Enter the corresponding A column figure in the appropriate space under COL-2.

(b) Locate the COL-1 final A value in the table. Enter the corresponding B figure in the appropriate space under COL-2.

(c) Subtract the COL-2 B value from the COL-2 value. The result is entered as the final COL-2 A value.

(d) Locate the final COL-2 A value in the table. The corresponding degrees and minutes will be entered as the K value under the DEGREES/MINUTES column.

Note. Before the K value is determined, refer to the special rules 1 or 2 and determine which is applicable to the GCAD computation.

7-8

FROM: _____ TO: _____

LAT: _____ LAT': _____

LONG: _____ LONG': _____

T is determined by the following conditions: If long and long' are the same name SUBTRACT. If long and long' are different names ADD.

T _____

DEGREES/MINUTES	COL-1 (ADD)	COL-2 (SUBTRACT)	COL-3 (ADD)	COL-4 (SUBTRACT)
T: _____	A: _____			
L': _____	B: _____	A: _____		
	A: _____	B: _____	B: _____	A: _____
K: _____		A: _____		
L: _____				
KL: _____			B: _____	
D ARC: _____			B: _____	A: _____
60 X DEGREES _____				A: _____
+ MINUTES _____				<B _____
TOTAL _____				
TRUE AZIMUTH _____				

Figure 7-4. GCAD computation worksheet.

If other logarithm tables are used instead of dead reckoning altitude and azimuth tables, column A equates to log cosecant, and column B equates to log secant.

(3) COL-3.

(a) The first COL-3 B value is a repeat of the COL-2 B value.

(b) Enter the LAT or L in the appropriate space under the DEGREES/MINUTES column.

(c) Determine the KL value under the DEGREES/MINUTES column, by subtracting the L or LAT value from the K value if the same name. Add K and L if different names.

(d) Locate the KL value in the table. Enter the corresponding B column value in the appropriate COL-3 space.

Note. If rule 2 is applicable to the computation, and the KL value exceeds 180 degrees, subtract 180 degrees before entering the table.

(e) Add the COL-3 B values. Enter the result as the final COL-3 B value.

(f) Locate the final COL-3 B value in the table. Enter the corresponding degrees and minutes as the D arc value under the DEGREES/MINUTES column.

Note. Refer to the applicable rule to determine if the D arc value is taken from the top or the bottom of the table.

(4) COL-4.

(a) The first COL-4 A value is a repeat of the final COL-1 A value.

(b) Locate the final COL-3 B value in the table. Enter the corresponding A value in the appropriate COL-4 A space.

(c) Subtract the COL-4 A values and enter the difference in the space provided.

(d) Locate the final COL-4 A value in the table. Enter the corresponding degrees and minutes as the COL-4 B value.

Note. Again refer to the applicable rule to determine if $\angle B$ is taken from the top or the bottom of the table, and if that value is the true azimuth.

(5) *Distance.* To compute the great circle azimuth distance:

(a) Multiply the number of D arc degrees by 60.

(b) Add the D arc minutes to the result. The sum indicates the distance in nautical miles. To obtain statute miles, multiply the nautical miles by 1.15.

f. GCAD Example. Determine the great circle azimuth and distance from Hetricks Villa, USA to London, England. The following information is provided.

Hetricks Villa, USA	Latitude: 42° 33' North
	Longitude: 71° 36' West
London, England	Latitude: 51° 32' North
	Longitude: 00° 05' West

Before beginning the computation, determine which rule is applicable. Since LONG and LONG' are the same name, *West*, rule 1 will apply.

Step 1. Determine the T value. Since LONG and LONG' are the same name, *West*, subtract to find the difference.

Hetricks Villa	LONG: 71° 36'
	—
London	LONG': 00° 05'
	<u>T = 71° 31'</u>

Step 2. Locate the T value, 71° 31', in the dead reckoning and azimuth table. The corresponding COL-1 A value is 2300.

Step 3. Locate the L' value, 51° 32', in the table. The corresponding COL-1 B value is 20617.

Step 4. Add the COL-1 A and B values. The result, or 22917, is the final COL-1 A value.

A	2300
	+
B	<u>20617</u>
	22917

Step 5. Locate the L' value, 51° 32', in the table. The corresponding COL-2 A value is 10625.

Step 6. Locate the COL-1 final A value, 22917, in the table. The corresponding COL-2 B value is 9292.

Step 7. Subtract the COL-2 B value, 9292, from the COL-2 A value, 10625. The remainder is 1333 and the final COL-2 A value.

$$\begin{array}{r} A \quad 10625 \\ - \\ B \quad \underline{9292} \\ 1333 \end{array}$$

Step 8. Locate the final COL-2 A value, 1333, in the table. The corresponding degrees and minutes, $75^{\circ} 52' 30''$ represents the K value.

Note. Refer to rule 1a to determine if K is selected from the top or the bottom of the table.

Step 9. Record the first COL-3 B value as 9292 since it is a repeat of the COL-2 B value.

Step 10. Enter the value for LAT, or $42^{\circ} 33'$, under the DEGREES/MINUTES column in the appropriate space.

Step 11. Determine the value for KL by subtracting LAT, $42^{\circ} 33'$ from the K value, $75^{\circ} 52' 30''$. The remainder is $33^{\circ} 19' 30''$.

$$\begin{array}{r} K \quad 75^{\circ} 52' 30'' \\ - \\ LAT \quad \underline{42^{\circ} 33'} \\ KL = 33^{\circ} 19' 30'' \end{array}$$

Step 12. Locate the KL value, $33^{\circ} 19' 30''$, in the table. The corresponding COL-3 B value is 7802.

Step 13. Add the COL-3 B values. The sum and final B value is 17094.

$$\begin{array}{r} B \quad 9292 \\ + \\ B \quad \underline{7802} \\ B = 17094 \end{array}$$

Step 14. Record the first COL-4 A value as 22917 since it is a repeat of the final COL-1 A value.

Step 15. Locate the COL-3 final B value, 17094, in the table. The corresponding COL-4 A value is 13185.

Step 16. Subtract the COL-4 A value, 13185, from 22917. The final COL-4 value is 9732.

$$\begin{array}{r} A \quad 22917 \\ - \\ A \quad \underline{13185} \\ A = 9732 \end{array}$$

Step 17. Locate the COL-4 final A value, 9732, in the table. Again refer to rule 1 and determine if $\angle B$ is taken from the top or the bottom of the table. Since K is greater than L, $\angle B$ is selected from the top of the table. Therefore, $\angle B$ or the true azimuth from Hetricks Villa to London, England is $53^{\circ} 03' 30''$. Again refer to the rule and determine if $\angle B$ is the true bearing. As the initial position is west of the final position, $53^{\circ} 03' 30''$ is the true azimuth.

Step 18. To determine D arc, locate the final COL-3 B value in the table. Refer to rule 1 to determine if D arc is taken from the top or the bottom of the table. Since T and KL are both less than 90 degrees, D arc is taken from the top of the table and is $47^{\circ} 34' 30''$.

Step 19. To compute the distance from the initial to the final position in nautical miles, multiply D arc by 60. To obtain statute miles, multiply the total nautical miles by 1.15.

$$\begin{array}{r} D \text{ arc} = 47^{\circ} 34' 30'' \\ 47 \times 60 = 2820 \\ + \quad \underline{34.5} \\ \text{Total nautical miles} = 2854.5 \\ 2854.5 \\ \times 1.15 \\ \hline 142 \ 725 \\ 285 \ 45 \\ \hline 2854 \ 5 \\ \text{Total statute miles} = 3282.675 \end{array}$$

Section III

STATISTICAL FACTORS

7-7. General.

Statistical analysis is an invaluable management tool for measuring direction-finding performance. Through the proper application of statistics, an estimate of the amount of error found in individual bearings can be provided, as well as the probable amount of error of the site, or even

the complete direction-finding net. Normally, plotting and evaluation activities are responsible for performing accuracy studies. However, direction-finding supervisors and analysts must be knowledgeable of statistical analysis procedures and must be able to compute the analytical computations outlined in this chapter.

7-8. Systematic Error.

Systematic error (SE) represents the difference between the true bearing and the mean bearing of a transmitter. The true bearing is determined by computing a great circle azimuth from the DF site to the selected target station. The average bearing is determined by taking a large number of bearings on the selected transmitter, a minimum of 200, and computing the average or mean bearing of the sample.

a. Consideration should be given to the following criteria when selecting a check station.

(1) The frequency should be compatible with operational targets.

(2) The location should be within the area of interest or a very close proximity thereof.

(3) The distance should not be significantly different than that of operational targets.

b. Systematic error is computed using the formula $SE = \text{Bearing Mean (BM)} - \text{Bearing True (BT)}$.

(1) BM is the mean bearing between the DF site and the selected check station.

(2) BT is the true bearing between the DF station and the selected check station.

c. The following steps outline the procedure for computing systematic error.

Step 1. Visually inspect the reported bearings and eliminate the obviously wild ones.

Step 2. Mathematically compute the mean bearing from the remaining bearings.

Step 3. Eliminate all bearings which deviate more than plus or minus 8 degrees from the computed mean bearing.

Step 4. Recompute the mean bearing.

Step 5. Determine the difference between the mean and true bearings. The difference is the systematic error.

Note. Systematic error must always be expressed as a negative or positive error. If the mean bearing is smaller than the true bearing, the error is negative. However, if the mean bearing is larger than the true bearing, the error is positive.

d. The following example illustrates the computation of systematic error using the formula $SE = BM - BT$. The true azimuth of the check station is 031 degrees. The following bearings were observed on the selected check station: 029°, 025°, 032°, 029°, 034°, 032°, 030°, 028°, 034°, and 027°.

Note. In practical applications at least 200 bearings must be obtained on the selected check station.

Step 1. A visual inspection proves there are no obvious wild bearings.

Step 2. Compute the mean bearing.

$$\begin{array}{r}
 029^{\circ} \\
 025^{\circ} \\
 032^{\circ} \\
 029^{\circ} \\
 034^{\circ} \\
 032^{\circ} \\
 030^{\circ} \\
 028^{\circ} \\
 034^{\circ} \\
 027^{\circ} \\
 \hline
 300 / 10 = 030^{\circ}
 \end{array}$$

Steps 3 and 4. Since there are no bearings which deviate over plus or minus 8 degrees from the computed mean bearing, proceed to step 5.

Step 5. Determine the difference between the mean and true bearings. The difference is the systematic error.

$$\begin{aligned} \text{SE} &= \text{BM} - \text{BT} \\ \text{SE} &= 030^\circ - 031^\circ \\ \text{SE} &= -001^\circ \end{aligned}$$

7-9. Variance.

Variance is used as a reliability factor and indicates the quality of bearings used in the computation of the mean bearing. Variance provides the measure of spread, or the dispersion of bearings around the mean bearing. The analysis of either site or individual operator variance on selected check stations provides the supervisor with an additional management tool for evaluating efficiency.

a. The formula for computing variance is:

$$\frac{(\text{BM} - \text{BO})^2}{N}$$

(1) Σ indicates the algebraic sum.

(2) $(\text{BM} - \text{BO})^2$ is the observed bearing subtracted from the mean bearing. The difference or remainder is then squared.

(3) N is the total number of bearings within plus or minus 8 degrees of the mean bearing.

b. The following steps outline the procedure for computing variance.

Step 1. Visually inspect all the reported bearings and eliminate the obviously wild ones.

Step 2. Mathematically compute the mean bearing from the remaining bearings.

Step 3. Eliminate any of the remaining bearings which deviate more than plus or minus 8 degrees from the computed mean.

Step 4. Recompute the mean if necessary.

Step 5. Determine the deviation of each observed bearing from the mean bearing and square each deviation.

Step 6. Add the squared deviations. Divide the sum by the total number of bearings used. The result is the variance.

Note. Due to the squaring process in step 5, variance has no sign.

c. The following bearings were observed on a selected check station: 330°, 326°, 333°, 334°, 325°, 330°, 331°, 329°, 328°, and 334°.

Note. In practical applications at least 200 bearings must be obtained on the selected check station.

Step 1. A visual inspection proves there are no obvious wild bearings.

Step 2. Compute the mean bearing.

$$\begin{array}{r} 330^\circ \\ 326^\circ \\ 333^\circ \\ 334^\circ \\ 325^\circ \\ 331^\circ \\ 330^\circ \\ 329^\circ \\ 328^\circ \\ 334^\circ \\ \hline 3300 / 10 = 330^\circ \end{array}$$

Steps 3 and 4. Since there are no bearings which deviate over plus or minus 8 degrees from the computed mean, proceed to step 5.

Step 5. Determine the deviation of each observed bearing from the mean bearing and square each deviation.

BM	BO	Remainder	Squared
330°	330°	= 0 ²	= 0
330°	326°	= 4 ²	= 16
330°	333°	= -3 ²	= 9
330°	334°	= -4 ²	= 16
330°	325°	= 5 ²	= 25
330°	331°	= -1 ²	= 1
330°	330°	= 0 ²	= 0
330°	329°	= 1 ²	= 1
330°	328°	= 2 ²	= 4
330°	334°	= -4	= 16

Step 6. Add the squared deviations and divide by the number of bearings used. The result is the variance.

$$\begin{array}{r}
 0 \\
 16 \\
 9 \\
 16 \\
 25 \\
 1 \\
 0 \\
 1 \\
 4 \\
 \hline
 16 \\
 88 / 10 = 8.8
 \end{array}$$

The variance is 8.8.

7-10. Square Root.

Before standard deviation (SD), another direction-finding statistical factor, can be addressed it is necessary to be able to manually compute square root. Although pocket calculators and other machine aids can perform this function much faster, the need for manual computation of square root may arise.

a. The following steps outline the procedure for obtaining the square root of the number 3.4.

Step 1. Starting at the decimal point, mark off the digits in pairs in both directions. Add zeros as necessary.

$$\sqrt{03.40\ 00}$$

Step 2. Place the decimal point for the answer directly above the decimal point that appears under the radical sign.

$$\sqrt{03.40\ 00}$$

Step 3. Determine by inspection the largest number that can be squared without exceeding the first pair of digits - 03. The answer is 1, since the square of any number larger than 1 will be greater than 03. Place the 1 above the first pair of digits.

$$\begin{array}{r}
 1. \\
 03.40\ 00
 \end{array}$$

Step 4. Square 1 obtaining 1 and place it under the 03. Subtract 1 from 03 obtaining 2. Bring down the next pair of digits.

$$\begin{array}{r}
 1. \\
 \sqrt{03.40\ 00} \\
 \underline{1} \\
 240
 \end{array}$$

Step 5. Double the answer or quotient of 1 obtaining 2. Place the 2 to the immediate left of the 240. Determine the number that can be multiplied by 2 and that same number and not exceed 240. The answer is 8 since $28 \times 8 = 224$. The number 9 would prove to be too large since $29 \times 9 = 261$. Place the number 8 to the right of the decimal in the quotient. Subtract the 224 from 240 and bring down the next pair of numbers - 00.

$$\begin{array}{r}
 1.8 \\
 \sqrt{03.40\ 00} \\
 \underline{1} \\
 28 \quad 240 \\
 \underline{224} \\
 16\ 00
 \end{array}$$

Step 6. Double the quotient 18, disregarding the decimal point, obtaining 36. Place the 36 to the left of the 1600. Determine the number that can be multiplied by 36 and that same number and not exceed 1600. The answer is 4 as $364 \times 4 = 1456$. The number 5 would be too large since $365 \times 5 = 1825$. Place the 4 above the second pair of digits.

$$\begin{array}{r}
 1.8\ 4 \\
 \sqrt{03.40\ 00} \\
 \underline{1} \\
 28 \quad 240 \\
 \underline{224} \\
 36 \quad 16\ 00 \\
 \underline{1456} \\
 144
 \end{array}$$

b. Depending on the degree of accuracy desired, one can continue the process indefinitely by adding zeros. For direction-finding purposes, two places to the right of the decimal are sufficient. For example, $(1.84)^2 = 3.3856$.

7-11. Standard Deviation (SD).

a. Standard deviation is perhaps the best statistical method of evaluating direction-finding site performance. Systematic error is indicative of average error, but standard deviation is representative of site reliability. SD is a probability figure which indicates the spread of bearings on one or more targets. In this respect, the smaller the number or SD, the greater the reliability that is attributed to the direction-finding site.

b. Standard deviation is computed using the formula:

$$SD = \sqrt{\frac{(BT - BO)^2 - (SE)^2}{N}}$$

(1) BT is the true bearing between the DF site and the selected check station.

(2) BO is the observed bearing of the selected check station.

(3) N is the total number of bearings, within plus or minus 8 degrees of the mean bearing, used in the computation.

(4) $(SE)^2$ is the systematic error squared.

c. The following steps outline the procedure for computing standard deviation.

Step 1. Compute the SE of a selected check station using a minimum of 200 bearings.

Step 2. Determine for each observed bearing the deviation in degrees from the true bearing. (If the true bearing on the selected check station is not known, a great circle azimuth must be computed.)

Step 3. Square each deviation.

Step 4. Add the squared deviations and divide the sum by the total number of bearings used in the computation, within plus or minus 8 degrees of the mean bearing. This step satisfies the $\frac{(BT - BO)^2}{N}$ portion of the formula.

Step 5. Square the SE obtained in step 1. Subtract the $(SE)^2$ from the number obtained in step 4.

Step 6. Compute the square root of the number obtained in step 5. The square root represents the standard deviation of the direction-finding site.

d. The following example illustrates the computation of standard deviation. To prevent a lengthy illustration, only 10 bearings are used and the following information is provided: SE = -001 degree, BT = 031 degrees. Bearings observed on the selected check station are: 029°, 025°, 032°, 029°, 034°, 032°, 030°, 028°, 034°, and 027°.

Step 1. An SE of -001 degree is provided.

Step 2. Subtract the BO from the BT.

BT	BO	Remainder
031°	- 029°	= 2°
031°	- 025°	= 6°
031°	- 032°	= - 1°
031°	- 029°	= 2°
031°	- 034°	= - 3°
031°	- 032°	= - 1°
031°	- 030°	= 1°
031°	- 028°	= 3°
031°	- 034°	= - 3°
031°	- 027°	= 4°

Step 3. Square the remainder obtained in step 2.

Remainder	Squared
2°	4
6°	36
- 1°	1
2°	4
- 3°	9
- 1°	1
1°	1
3°	9
- 3°	9
4°	16

Step 4. Add the squared deviations and divide by the total number of bearings used in the computation.

$$\begin{array}{r}
 4 \\
 36 \\
 1 \\
 4 \\
 9 \\
 1 \\
 1 \\
 9 \\
 9 \\
 \hline
 16 \\
 90 / 10 = 9
 \end{array}$$

This step satisfies $\frac{(BT - BO)^2}{N}$ portion of the formula.

Step 5. Square the SE and subtract the result from the number obtained in step 4.

$$\begin{array}{l}
 \sqrt{9 - (SE)^2} \\
 \sqrt{9 - (-001)^2} \\
 \sqrt{9 - 1} \\
 \sqrt{8}
 \end{array}$$

Step 6. Compute the square root.

$$\begin{array}{r}
 \sqrt{8} \\
 2. \quad 8 \quad 2 \\
 \hline
 \sqrt{08. \quad 00 \quad 00} \\
 4 \\
 48 \quad 4 \quad 00 \\
 3 \quad 84 \\
 562 \quad 16 \quad 00 \\
 11 \quad 24 \\
 \hline
 4 \quad 76
 \end{array}$$

Standard deviation equals 2.82.



APPENDIX A

REFERENCES

A-1. Army Regulation (AR).

310-25 Dictionary of United States Army Terms.

A-2. Field Manual (FM).

11-60 Communications-Electronics Fundamentals: Basic Principles
Direct Current.
21-26 Map Reading.

A-3. Technical Manual (TM).

11-665 CW and AM Radio Transmitters and Receivers.
11-666 Antennas and Radio Propagation.
11-681 Electrical Fundamentals (Alternating Current).
11-5825-231-25 Direction Finder Set AN/TRD-15.

A-4. USASA Regulation (USASA Reg).

(C-CC0) USASA Standard Criteria for Supervision and
Regulations Employment of USASA Direction Finding
105-13 Techniques (U).

A-5. Training Film (TF).

TF 32-4106 Direction Finder Set AN/TRD-15/23 (Pattern
Interpretation).

Appendix B

COMMON LOGARITHMS OF FUNCTIONS OF
ANGLES IN DEGREES AND MINUTES

0°... 180°	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
90°... 270°	L COS		L COT		L TAN	L SIN	
0	—		—		—	0.00 000	60
1	6.46 373	30103	6.46 373	30103	3.53 627	0.00 000	59
2	6.76 476	17609	6.76 476	17609	3.23 524	0.00 000	58
3	6.94 085	12494	6.94 085	12494	3.05 916	0.00 000	57
4	7.06 579	9691	7.06 579	9691	2.93 421	0.00 000	56
5	7.16 270		7.16 270		2.83 730	0.00 000	55
6	7.24 188	7918	7.24 188	7918	2.75 812	0.00 000	54
7	7.30 882	6694	7.30 882	6694	2.69 118	0.00 000	53
8	7.36 682	5800	7.36 682	5800	2.63 318	0.00 000	52
9	7.41 797	5115	7.41 797	5115	2.58 203	0.00 000	51
10	7.46 373	4576	7.46 373	4576	2.53 627	0.00 000	50
11	7.50 512	4139	7.50 512	4139	2.49 488	0.00 000	49
12	7.54 291	3779	7.54 291	3779	2.45 709	0.00 000	48
13	7.57 767	3476	7.57 767	3476	2.42 233	0.00 000	47
14	7.60 985	3218	7.60 985	3218	2.39 014	0.00 000	46
15	7.63 982	2997	7.63 982	2997	2.36 018	0.00 000	45
16	7.66 784	2802	7.66 784	2802	2.33 215	0.00 000	44
17	7.69 417	2633	7.69 417	2633	2.30 582	9.99 999	43
18	7.71 900	2483	7.71 900	2483	2.28 100	9.99 999	42
19	7.74 248	2348	7.74 248	2348	2.25 752	9.99 999	41
20	7.76 475	2227	7.76 475	2227	2.23 524	9.99 999	40
21	7.78 594	2119	7.78 594	2119	2.21 405	9.99 999	39
22	7.80 615	2021	7.80 615	2021	2.19 385	9.99 999	38
23	7.82 545	1930	7.82 545	1930	2.17 454	9.99 999	37
24	7.84 393	1848	7.84 393	1848	2.15 606	9.99 999	36
25	7.86 166	1773	7.86 166	1773	2.13 833	9.99 999	35
26	7.87 870	1704	7.87 870	1704	2.12 129	9.99 999	34
27	7.89 509	1639	7.89 509	1639	2.10 490	9.99 999	33
28	7.91 088	1579	7.91 088	1579	2.08 911	9.99 999	32
29	7.92 612	1524	7.92 612	1524	2.07 387	9.99 998	31
30	7.94 084	1472	7.94 084	1472	2.05 914	9.99 998	30
31	7.95 508	1424	7.95 508	1424	2.04 490	9.99 998	29
32	7.96 887	1379	7.96 887	1379	2.03 111	9.99 998	28
33	7.98 223	1336	7.98 223	1336	2.01 775	9.99 998	27
34	7.99 520	1297	7.99 520	1297	2.00 478	9.99 998	26
35	8.00 779	1259	8.00 779	1259	1.99 219	9.99 998	25
36	8.02 002	1223	8.02 002	1223	1.97 996	9.99 998	24
37	8.03 192	1190	8.03 192	1190	1.96 806	9.99 997	23
38	8.04 350	1158	8.04 350	1158	1.95 647	9.99 997	22
39	8.05 478	1128	8.05 478	1128	1.94 519	9.99 997	21
40	8.06 578	1100	8.06 578	1100	1.93 419	9.99 997	20
41	8.07 650	1072	8.07 650	1072	1.92 347	9.99 997	19
42	8.08 696	1046	8.08 696	1046	1.91 300	9.99 997	18
43	8.09 718	1022	8.09 718	1022	1.90 278	9.99 997	17
44	8.10 717	999	8.10 717	999	1.89 280	9.99 996	16
45	8.11 693	976	8.11 693	976	1.88 304	9.99 996	15
46	8.12 647	954	8.12 647	954	1.87 349	9.99 996	14
47	8.13 581	934	8.13 581	934	1.86 415	9.99 996	13
48	8.14 495	914	8.14 495	914	1.85 500	9.99 996	12
49	8.15 391	896	8.15 391	896	1.84 605	9.99 996	11
50	8.16 268	877	8.16 268	877	1.83 727	9.99 995	10
51	8.17 128	860	8.17 128	860	1.82 867	9.99 995	9
52	8.17 971	843	8.17 971	843	1.82 024	9.99 995	8
53	8.18 798	827	8.18 798	827	1.81 106	9.99 995	7
54	8.19 610	812	8.19 610	812	1.80 384	9.99 995	6
55	8.20 407	797	8.20 407	797	1.79 587	9.99 994	5
56	8.21 189	782	8.21 189	782	1.78 805	9.99 994	4
57	8.21 958	769	8.21 958	769	1.78 036	9.99 994	3
58	8.22 713	755	8.22 713	755	1.77 280	9.99 994	2
59	8.23 456	743	8.23 456	743	1.76 538	9.99 994	1
60	8.24 186	730	8.24 186	730	1.75 808	9.99 993	0
	L SIN	D	L TAN	CD	L COT	L COS	359°... 179°...
	L COS		L COT		L TAN	L SIN	269°... 89°...

1°... 181°	L SIN	O	L TAN	CO	L COT	L COS	PROP. PTS.
91°... 271°	L COS		L COT		L TAN	L SIN	
0	8.24 186	717	8.24 192	718	1.75 808	9.99 993	60
1	8.24 903	706	8.24 910	706	1.75 090	9.99 993	59
2	8.25 609	695	8.25 616	696	1.74 384	9.99 993	58
3	8.26 304	684	8.26 312	684	1.73 688	9.99 993	57
4	8.26 988	673	8.26 996	673	1.73 004	9.99 992	56
5	8.27 661	663	8.27 669	663	1.72 331	9.99 992	55
6	8.28 324	653	8.28 332	654	1.71 668	9.99 992	54
7	8.28 977	644	8.28 986	643	1.71 014	9.99 992	53
8	8.29 621	634	8.29 629	634	1.70 371	9.99 992	52
9	8.30 255	624	8.30 263	625	1.69 737	9.99 991	51
10	8.30 871	616	8.30 888	617	1.69 112	9.99 991	50
11	8.31 465	608	8.31 505	607	1.68 495	9.99 991	49
12	8.32 103	599	8.32 112	599	1.67 888	9.99 990	48
13	8.32 702	590	8.32 711	591	1.67 289	9.99 990	47
14	8.33 292	583	8.33 302	584	1.66 698	9.99 990	46
15	8.33 875	575	8.33 886	575	1.66 114	9.99 990	45
16	8.34 450	568	8.34 461	568	1.65 539	9.99 989	44
17	8.35 018	560	8.35 029	561	1.64 971	9.99 989	43
18	8.35 578	553	8.35 590	553	1.64 410	9.99 989	42
19	8.36 131	547	8.36 143	546	1.63 857	9.99 989	41
20	8.36 678	539	8.36 689	540	1.63 311	9.99 988	40
21	8.37 217	533	8.37 229	533	1.62 771	9.99 988	39
22	8.37 750	526	8.37 762	527	1.62 238	9.99 988	38
23	8.38 276	520	8.38 289	520	1.61 711	9.99 987	37
24	8.38 796	514	8.38 809	514	1.61 191	9.99 987	36
25	8.39 810	506	8.39 832	509	1.60 677	9.99 987	35
26	8.39 818	502	8.39 832	502	1.60 168	9.99 986	34
27	8.40 320	496	8.40 334	496	1.59 666	9.99 986	33
28	8.40 816	491	8.40 830	491	1.59 170	9.99 986	32
29	8.41 307	485	8.41 321	486	1.58 679	9.99 985	31
30	8.41 792	480	8.41 807	480	1.58 193	9.99 985	30
31	8.42 272	474	8.42 287	475	1.57 713	9.99 985	29
32	8.42 746	470	8.42 762	470	1.57 238	9.99 984	28
33	8.43 216	464	8.43 232	464	1.56 768	9.99 984	27
34	8.43 680	459	8.43 696	460	1.56 304	9.99 984	26
35	8.44 139	455	8.44 156	455	1.55 844	9.99 983	25
36	8.44 594	450	8.44 611	450	1.55 389	9.99 983	24
37	8.45 044	445	8.45 061	446	1.54 939	9.99 983	23
38	8.45 489	441	8.45 507	441	1.54 493	9.99 982	22
39	8.45 930	438	8.45 948	437	1.54 052	9.99 982	21
40	8.46 366	433	8.46 385	432	1.53 615	9.99 982	20
41	8.46 799	427	8.46 817	428	1.53 183	9.99 981	19
42	8.47 226	424	8.47 245	424	1.52 755	9.99 981	18
43	8.47 650	419	8.47 669	420	1.52 331	9.99 981	17
44	8.48 069	416	8.48 089	416	1.51 911	9.99 980	16
45	8.48 485	411	8.48 505	412	1.51 495	9.99 980	15
46	8.48 896	408	8.48 917	408	1.51 083	9.99 979	14
47	8.49 304	404	8.49 325	404	1.50 675	9.99 979	13
48	8.49 708	400	8.49 729	401	1.50 271	9.99 979	12
49	8.50 108	396	8.50 130	397	1.49 870	9.99 978	11
50	8.50 504	393	8.50 527	393	1.49 473	9.99 978	10
51	8.50 897	390	8.50 920	390	1.49 080	9.99 977	9
52	8.51 287	388	8.51 310	386	1.48 690	9.99 977	8
53	8.51 673	382	8.51 696	383	1.48 304	9.99 977	7
54	8.52 055	379	8.52 079	380	1.47 921	9.99 976	6
55	8.52 434	376	8.52 459	376	1.47 541	9.99 976	5
56	8.52 810	373	8.52 835	373	1.47 165	9.99 975	4
57	8.53 183	369	8.53 208	370	1.46 792	9.99 975	3
58	8.53 552	367	8.53 578	367	1.46 422	9.99 974	2
59	8.53 919	363	8.53 945	363	1.46 055	9.99 974	1
60	8.54 282		8.54 308		1.45 692	9.99 974	0
	L SIN	O	L TAN	CD	L COT	L COS	358°... 178°
	L COS		L COT		L TAN	L SIN	268°... 88°

2° ... 182°	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
92° ... 272°	L COS		L COT		L TAN	L SIN	
0	8.54 282	360	8.54 308	361	1.45 692	9.99 974	60
1	8.54 642	357	8.54 669	358	1.45 331	9.99 973	59
2	8.54 999	355	9.55 027	355	1.44 973	9.99 973	58
3	8.55 354	351	9.55 382	352	1.44 618	9.99 972	57
4	8.55 705	349	8.55 734	349	1.44 266	9.99 972	56
5	8.56 054	346	8.56 083	346	1.43 917	9.99 971	55
6	8.56 400	343	8.56 429	344	1.43 571	9.99 971	54
7	8.56 743	341	8.56 773	341	1.43 227	9.99 970	53
8	8.57 084	337	8.57 114	338	1.42 886	9.99 970	52
9	8.57 421	336	8.57 452	336	1.42 548	9.99 969	51
10	8.57 757	332	8.57 788	333	1.42 212	9.99 969	50
11	8.58 089	330	8.58 121	330	1.41 879	9.99 968	49
12	8.58 419	328	8.58 451	328	1.41 549	9.99 968	48
13	8.58 747	325	8.58 779	326	1.41 221	9.99 967	47
14	8.59 072	323	8.59 105	323	1.40 895	9.99 967	46
15	8.59 395	320	8.59 428	321	1.40 572	9.99 967	45
16	8.59 715	318	8.59 749	319	1.40 251	9.99 966	44
17	8.60 033	316	8.60 068	316	1.39 932	9.99 966	43
18	8.60 349	313	8.60 384	314	1.39 616	9.99 965	42
19	8.60 662	311	8.60 698	311	1.39 302	9.99 964	41
20	8.60 973	309	8.61 009	310	1.38 991	9.99 964	40
21	8.61 282	307	8.61 319	307	1.38 681	9.99 963	39
22	8.61 589	305	8.61 626	305	1.38 374	9.99 963	38
23	8.61 894	302	8.61 931	303	1.38 069	9.99 962	37
24	8.62 196	301	8.62 234	301	1.37 766	9.99 962	36
25	8.62 497	298	8.62 535	299	1.37 465	9.99 961	35
26	8.62 795	296	8.62 834	297	1.37 166	9.99 961	34
27	8.63 091	294	8.63 131	295	1.36 869	9.99 960	33
28	8.63 385	293	8.63 426	292	1.36 574	9.99 960	32
29	8.63 678	290	8.63 718	291	1.36 282	9.99 959	31
30	8.63 963	288	8.64 009	289	1.35 991	9.99 959	30
31	8.64 256	287	8.64 298	287	1.35 702	9.99 958	29
32	8.64 543	284	8.64 585	285	1.35 415	9.99 958	28
33	8.64 827	283	8.64 870	284	1.35 130	9.99 957	27
34	8.65 110	281	8.65 154	281	1.34 846	9.99 956	26
35	8.65 391	279	8.65 435	280	1.34 565	9.99 956	25
36	8.65 670	277	8.65 715	278	1.34 285	9.99 955	24
37	8.65 947	276	8.65 993	276	1.34 007	9.99 955	23
38	8.66 223	274	8.66 269	274	1.33 731	9.99 954	22
39	8.66 497	272	8.66 543	273	1.33 457	9.99 954	21
40	8.66 769	270	8.66 816	271	1.33 184	9.99 953	20
41	8.67 039	269	8.67 087	269	1.32 913	9.99 952	19
42	8.67 308	267	8.67 356	268	1.32 644	9.99 952	18
43	8.67 575	266	8.67 624	266	1.32 376	9.99 951	17
44	8.67 841	263	8.67 890	264	1.32 110	9.99 951	16
45	8.68 104	263	8.68 154	263	1.31 846	9.99 950	15
46	8.68 367	260	8.68 417	261	1.31 583	9.99 949	14
47	8.68 627	259	8.68 678	260	1.31 322	9.99 949	13
48	8.68 886	258	8.68 938	258	1.31 062	9.99 948	12
49	8.69 144	256	8.69 196	257	1.30 804	9.99 948	11
50	8.69 400	254	8.69 453	255	1.30 547	9.99 947	10
51	8.69 654	253	8.69 708	254	1.30 292	9.99 946	9
52	8.69 907	252	8.69 962	252	1.30 038	9.99 946	8
53	8.70 159	250	8.70 214	251	1.29 786	9.99 945	7
54	8.70 409	249	8.70 465	249	1.29 535	9.99 944	6
55	8.70 658	247	8.70 714	248	1.29 286	9.99 944	5
56	8.70 905	246	8.70 962	246	1.29 038	9.99 943	4
57	8.71 151	244	8.71 208	245	1.28 792	9.99 942	3
58	8.71 395	243	8.71 453	244	1.28 547	9.99 942	2
59	8.71 638	242	8.71 697	243	1.28 303	9.99 941	1
60	8.71 880		8.71 940		1.28 060	9.99 940	0
	L SIN	D	L TAN	CD	L COT	L COS	357° ... 177°
	L COS		L COT		L TAN	L SIN	267° ... 87°

3°... 183°...	L SIN	D	L TAN	CD	L COT	L COS		PROP. PTS.		
93°... 273°...	L COS		L COT		L TAN	L SIN				
0	8.71 880	240	8.71 940	241	1.28 080	9.99 940	60	238'	234	229
1	8.72 120	239	8.72 181	239	1.27 819	9.99 940	59	23.8	23.4	22.9
2	8.72 359	239	8.72 420	239	1.27 580	9.99 939	58	47.6	46.8	45.8
3	8.72 597	237	8.72 659	237	1.27 341	9.99 938	57	71.4	70.2	68.7
4	8.72 834	235	8.72 896	236	1.27 104	9.99 938	56	95.2	93.6	91.6
5	8.73 069	234	8.73 132	234	1.26 868	9.99 937	55	119.0	117.0	114.5
6	8.73 303	232	8.73 366	234	1.26 634	9.99 936	54	142.8	140.4	137.4
7	8.73 535	232	8.73 600	232	1.26 400	9.99 936	53	166.8	163.8	160.3
8	8.73 767	230	8.73 832	230	1.26 168	9.99 935	52	190.4	187.2	183.2
9	8.73 997	229	8.74 063	229	1.25 937	9.99 934	51	214.2	210.6	206.1
10	8.74 226	228	8.74 292	229	1.25 708	9.99 934	50	225	230	216
11	8.74 454	226	8.74 521	227	1.25 479	9.99 933	49	22.5	22.0	21.6
12	8.74 680	226	8.74 748	226	1.25 252	9.99 932	48	45.0	44.0	43.2
13	8.74 906	224	8.74 974	225	1.25 026	9.99 932	47	67.5	66.0	64.8
14	8.75 130	223	8.75 199	224	1.24 801	9.99 931	46	90.0	88.0	86.4
15	8.75 353	222	8.75 423	222	1.24 577	9.99 930	45	112.5	110.0	108.0
16	8.75 575	220	8.75 645	222	1.24 355	9.99 929	44	135.0	132.0	129.6
17	8.75 795	220	8.75 867	220	1.24 133	9.99 929	43	157.5	154.0	151.2
18	8.76 015	219	8.76 087	219	1.23 913	9.99 928	42	180.0	178.0	172.8
19	8.76 234	217	8.76 308	219	1.23 694	9.99 927	41	202.5	198.0	194.4
20	8.76 451	216	8.76 525	217	1.23 475	9.99 926	40	212	208	204
21	8.76 667	216	8.76 742	216	1.23 258	9.99 926	39	21.2	20.8	20.4
22	8.76 883	214	8.76 958	215	1.23 042	9.99 925	38	42.4	41.6	40.8
23	8.77 097	213	8.77 173	214	1.22 827	9.99 924	37	63.6	62.4	61.2
24	8.77 310	212	8.77 387	213	1.22 613	9.99 923	36	84.8	83.2	81.8
25	8.77 522	211	8.77 600	211	1.22 400	9.99 923	35	106.0	104.0	102.0
26	8.77 733	210	8.77 811	211	1.22 189	9.99 922	34	127.2	124.8	122.4
27	8.77 943	209	8.78 022	210	1.21 978	9.99 921	33	148.4	145.6	142.8
28	8.78 152	208	8.78 232	209	1.21 768	9.99 920	32	169.6	166.4	163.2
29	8.78 360	208	8.78 441	208	1.21 559	9.99 920	31	190.8	187.2	183.6
30	8.78 568	206	8.78 649	206	1.21 351	9.99 919	30	201	197	193
31	8.78 774	205	8.78 855	206	1.21 145	9.99 918	29	20.1	19.7	19.3
32	8.78 979	204	8.79 061	205	1.20 939	9.99 917	28	40.2	39.4	38.8
33	8.79 138	203	8.79 266	204	1.20 734	9.99 917	27	60.3	59.1	57.9
34	8.79 386	202	8.79 470	203	1.20 530	9.99 916	26	80.4	78.8	77.2
35	8.79 588	201	8.79 673	202	1.20 327	9.99 915	25	100.5	98.5	96.5
36	8.79 789	201	8.79 875	201	1.20 125	9.99 914	24	120.8	118.2	115.8
37	8.79 990	199	8.80 076	201	1.19 924	9.99 913	23	140.7	137.9	135.1
38	8.80 189	199	8.80 277	199	1.19 723	9.99 913	22	160.8	157.6	154.4
39	8.80 388	197	8.80 476	198	1.19 524	9.99 912	21	180.9	177.3	173.7
40	8.80 585	197	8.80 674	198	1.19 326	9.99 911	20	189	185	181
41	8.80 782	196	8.80 872	196	1.19 128	9.99 910	19	18.9	18.5	18.1
42	8.80 978	195	8.81 068	196	1.18 932	9.99 909	18	37.8	37.0	36.2
43	8.81 173	194	8.81 264	195	1.18 736	9.99 909	17	56.7	55.5	54.3
44	8.81 367	193	8.81 459	194	1.18 541	9.99 908	16	75.6	74.0	72.4
45	8.81 560	192	8.81 653	193	1.18 347	9.99 907	15	94.5	92.5	90.5
46	8.81 752	192	8.81 846	192	1.18 154	9.99 906	14	113.4	111.0	108.6
47	8.81 944	190	8.82 038	192	1.17 962	9.99 905	13	132.3	129.5	126.7
48	8.82 134	190	8.82 230	190	1.17 770	9.99 904	12	151.2	148.0	144.8
49	8.82 324	189	8.82 420	190	1.17 580	9.99 904	11	170.1	166.5	162.9
50	8.82 513	188	8.82 610	189	1.17 390	9.99 903	10	4	3	2
51	8.82 701	187	8.82 799	188	1.17 201	9.99 902	9	0.4	0.3	0.2
52	8.82 888	187	8.82 987	188	1.17 013	9.99 901	8	0.8	0.6	0.4
53	8.83 075	186	8.83 175	186	1.16 825	9.99 900	7	1.2	0.9	0.6
54	8.83 261	185	8.83 361	186	1.16 639	9.99 899	6	1.6	1.2	0.8
55	8.83 446	184	8.83 547	185	1.16 453	9.99 898	5	2.0	1.5	1.0
56	8.83 630	183	8.83 732	184	1.16 268	9.99 898	4	2.4	1.8	1.2
57	8.83 813	183	8.83 916	184	1.16 084	9.99 897	3	2.8	2.1	1.4
58	8.83 996	181	8.84 100	182	1.15 900	9.99 898	2	3.2	2.4	1.6
59	8.84 177	181	8.84 282	182	1.15 718	9.99 895	1	3.6	2.7	1.8
60	8.84 358		8.84 464		1.15 536	9.99 894	0			
	L SIN	D	L TAN	CD	L COT	L COS		356°... 176°...		
	L COS		L COT		L TAN	L SIN		266°... 86°..		

4°... 184°	L SIN	D	L TAN	CD	L COT	L COS		PROP. PTS			
94°... 274°	L COS		L COT		L TAN	L SIN					
0	8.84 358	181	8.84 464	182	1.15 536	9.99 894	60		181	179	177
1	8 84 539	179	8.84 646	180	1.15 354	9.99 892	59	1	18.1	17.9	17.7
2	8.84 718	179	8.84 826	180	1.15 174	9.99 892	58	2	36.2	35.8	35.4
3	8.84 897	178	8.85 006	179	1.14 994	9.99 891	57	3	54.3	53.7	53.1
4	8.85 075	177	8.85 185	178	1.14 815	9.99 891	56	4	72.4	71.6	70.8
5	8.85 252	177	8.85 363	177	1.14 637	9.99 890	55	5	90.5	89.5	88.5
6	8.85 429	176	8.85 540	177	1.14 460	9.99 889	54	6	108.6	107.4	106.2
7	8.85 605	175	8.85 717	176	1.14 283	9.99 888	53	7	126.7	125.3	123.9
8	8.85 780	175	8.85 893	176	1.14 107	9.99 887	52	8	144.8	143.2	141.6
9	8.85 955	173	8.86 069	174	1.13 931	9.99 886	51	9	162.9	161.1	159.3
10	8.86 128	173	8.86 243	174	1.13 757	9.99 885	50		175	173	171
11	8.86 301	173	8.86 417	174	1.13 583	9.99 884	49	1	17.5	17.3	17.1
12	8.86 474	171	8.86 591	172	1.13 409	9.99 883	48	2	35.0	34.6	34.2
13	8.86 645	171	8.86 763	172	1.13 237	9.99 882	47	3	52.5	51.9	51.3
14	8.86 816	171	8.86 935	171	1.13 065	9.99 881	46	4	70.0	69.2	68.4
15	8.86 987	169	8.87 106	171	1.12 894	9.99 880	45	5	87.5	86.5	85.5
16	8.87 156	169	8.87 277	170	1.12 723	9.99 879	44	6	105.0	103.8	102.6
17	8.87 325	169	8.87 447	169	1.12 553	9.99 879	43	7	122.5	121.1	119.7
18	8.87 494	167	8.87 616	169	1.12 384	9.99 878	42	8	140.0	138.4	136.8
19	8.87 661	168	8.87 785	168	1.12 215	9.99 877	41	9	157.5	155.7	153.9
20	8.87 829	166	8.87 953	167	1.12 047	9.99 876	40		168	166	164
21	8.87 995	166	8.88 120	167	1.11 880	9.99 875	39	1	16.8	16.6	16.4
22	8.88 161	165	8.88 287	166	1.11 713	9.99 874	38	2	33.6	32.2	32.8
23	8.88 326	164	8.88 453	165	1.11 547	9.99 873	37	3	50.4	49.8	49.2
24	8.88 490	164	8.88 618	165	1.11 382	9.99 872	36	4	67.2	66.4	65.6
25	8.88 654	163	8.88 783	165	1.11 217	9.99 871	35	5	84.0	83.0	82.0
26	8.88 817	163	8.88 948	163	1.11 052	9.99 870	34	6	100.8	99.6	98.4
27	8.88 980	162	8.89 111	163	1.10 889	9.99 869	33	7	117.6	116.2	114.8
28	8.89 142	162	8.89 274	163	1.10 726	9.99 868	32	8	134.4	132.8	131.2
29	8.89 304	160	8.89 437	161	1.10 563	9.99 867	31	9	151.2	149.4	147.6
30	8.89 464	161	8.89 598	162	1.10 402	9.99 866	30		162	159	157
31	8.89 625	159	8.89 760	160	1.10 240	9.99 865	29	1	16.2	15.9	15.7
32	8.89 784	159	8.89 920	160	1.10 080	9.99 864	28	2	32.4	31.8	31.4
33	8.89 943	159	8.90 080	160	1.09 920	9.99 863	27	3	48.6	47.7	47.1
34	8.90 102	158	8.90 240	159	1.09 760	9.99 862	26	4	64.8	63.6	62.8
35	8.90 260	157	8.90 399	158	1.09 601	9.99 861	25	5	81.0	79.5	78.5
36	8.90 417	157	8.90 557	158	1.09 443	9.99 860	24	6	97.2	95.4	94.2
37	8.90 574	156	8.90 715	157	1.09 285	9.99 859	23	7	113.4	111.3	109.9
38	8.90 730	155	8.90 872	157	1.09 128	9.99 858	22	8	129.6	127.2	125.6
39	8.90 885	155	8.91 029	156	1.08 971	9.99 857	21	9	145.8	143.1	141.3
40	8.91 040	155	8.91 185	155	1.08 815	9.99 856	20		155	153	151
41	8.91 195	154	8.91 340	155	1.08 660	9.99 855	19	1	15.5	15.3	15.1
42	8.91 349	153	8.91 495	155	1.08 505	9.99 854	18	2	31.0	30.6	30.2
43	8.91 502	153	8.91 650	153	1.08 350	9.99 853	17	3	46.5	45.9	45.3
44	8.91 655	152	8.91 803	154	1.08 197	9.99 852	16	4	62.0	61.2	60.4
45	8.91 807	152	8.91 957	153	1.08 043	9.99 851	15	5	77.5	76.5	75.5
46	8.91 959	151	8.92 110	152	1.07 890	9.99 850	14	6	93.0	91.8	90.6
47	8.92 110	151	8.92 262	152	1.07 738	9.99 848	13	7	108.5	107.1	105.7
48	8.92 261	150	8.92 414	151	1.07 586	9.99 847	12	8	124.0	122.4	120.8
49	8.92 411	150	8.92 565	151	1.07 435	9.99 846	11	9	139.5	137.7	135.9
50	8.92 561	149	8.92 716	150	1.07 284	9.99 845	10		149	147	1
51	8.92 710	149	8.92 866	150	1.07 134	9.99 844	9	1	14.9	14.7	0.1
52	8.92 859	148	8.92 016	149	1.06 984	9.99 843	8	2	29.8	29.4	0.2
53	8.93 077	147	8.93 165	148	1.06 835	9.99 842	7	3	44.7	44.1	0.3
54	8.93 154	147	8.93 313	149	1.06 687	9.99 841	6	4	59.6	58.8	0.4
55	8.93 301	147	8.93 462	147	1.06 538	9.99 840	5	5	74.5	73.5	0.5
56	8.93 448	146	8.93 609	147	1.06 391	9.99 839	4	6	89.4	88.2	0.6
57	8.93 594	146	8.93 756	147	1.06 244	9.99 838	3	7	104.3	102.9	0.7
58	8.93 740	145	8.93 903	146	1.06 097	9.99 837	2	8	119.2	117.6	0.8
59	8.93 885	145	8.94 049	146	1.05 951	9.99 836	1	9	134.1	132.3	0.9
60	8.94 030		8.94 195		1 05 805	9.99 834	0				
	L SIN	D	L TAN	CD	L COT	L COS		355°... 175°			
	L COS		L COT		L TAN	L SIN		265°... 85°			

5°... 185°...	L SIN	D	L TAN	CD	L COT	L COS	PROP PTS.			
95°... 275°...	L COS		L COT		L TAN	L SIN				
0	8.94 030	144	8.94 195	145	1.05 805	9.99 834	60	145	143	141
1	8.94 174	143	8.94 340	145	1.05 660	9.99 833	59	1	14.5	14.3
2	8.94 317	144	8.94 458	145	1.05 515	9.99 832	58	2	29.0	28.6
3	8.94 461	142	8.94 630	143	1.05 370	9.99 831	57	3	43.5	42.9
4	8.94 603	143	8.94 773	144	1.05 227	9.99 830	56	4	58.0	57.2
5	8.94 746	141	8.94 917	143	1.05 083	9.99 829	55	5	72.5	71.5
6	8.94 887	142	8.95 060	142	1.04 940	9.99 828	54	6	87.0	85.8
7	8.95 029	141	8.95 202	142	1.04 798	9.99 827	53	7	101.5	100.1
8	8.95 170	140	8.95 344	142	1.04 656	9.99 825	52	8	116.0	114.4
9	9.95 310	140	8.95 486	141	1.04 514	9.99 824	51	9	130.5	128.7
10	8.95 450	139	8.95 627	140	1.04 373	9.99 823	50	139	138	136
11	8.95 589	139	8.95 767	141	1.04 233	9.99 822	49	1	13.9	13.8
12	8.95 728	139	8.95 908	139	1.04 092	9.99 821	48	2	27.8	27.6
13	8.95 867	138	8.96 047	140	1.03 953	9.99 820	47	3	41.7	41.4
14	8.95 005	138	8.96 187	138	1.03 813	9.99 819	46	4	55.6	55.2
15	8.96 143	137	8.96 325	139	1.03 675	9.99 817	45	5	69.5	69.0
16	8.96 280	137	8.96 464	138	1.03 536	9.99 816	44	6	83.4	82.8
17	8.96 417	136	8.96 602	137	1.03 398	9.99 815	43	7	97.3	96.6
18	8.96 553	136	8.96 739	138	1.03 261	9.99 814	42	8	111.2	110.4
19	8.96 689	136	8.96 877	136	1.03 123	9.99 813	41	9	125.1	124.2
20	8.96 825	135	8.97 013	137	1.02 987	9.99 812	40	135	133	131
21	8.96 960	135	8.97 150	135	1.02 850	9.99 810	39	1	13.5	13.3
22	8.97 095	134	8.97 285	136	1.02 715	9.99 809	38	2	27.0	26.6
23	8.97 229	134	8.97 421	135	1.02 579	9.99 808	37	3	40.5	39.9
24	8.97 363	133	8.97 556	135	1.02 444	9.99 807	36	4	54.0	53.2
25	8.97 496	133	8.97 691	134	1.02 309	9.99 806	35	5	67.5	66.5
26	8.97 629	133	8.97 825	134	1.02 175	9.99 804	34	6	81.0	79.8
27	8.97 762	132	8.97 959	133	1.02 041	9.99 803	33	7	94.5	93.1
28	8.97 894	132	8.98 002	133	1.01 908	9.99 802	32	8	108.0	106.4
29	8.98 026	131	8.98 225	133	1.01 775	9.99 801	31	9	121.5	119.7
30	8.98 157	131	8.98 358	132	1.01 642	9.99 800	30	129	128	126
31	8.98 288	131	8.98 490	132	1.01 510	9.99 798	29	1	12.9	12.8
32	8.98 419	130	8.98 622	131	1.01 378	9.99 797	28	2	25.8	25.6
33	8.98 549	130	8.98 753	131	1.01 247	9.99 796	27	3	38.7	38.4
34	8.98 679	129	8.98 884	131	1.01 116	9.99 795	26	4	51.6	51.2
35	8.98 808	129	8.99 015	130	1.00 985	9.99 793	25	5	64.5	64.0
36	8.98 937	129	8.99 145	130	1.00 855	9.99 792	24	6	77.4	76.8
37	8.99 066	128	8.99 275	130	1.00 725	9.99 791	23	7	90.3	89.6
38	8.99 194	128	8.99 405	129	1.00 595	9.99 790	22	8	103.2	102.4
39	8.99 322	128	8.99 534	128	1.00 466	9.99 788	21	9	116.1	115.2
40	8.99 450	127	8.99 662	129	1.00 338	9.99 787	20	125	123	122
41	8.99 577	127	8.99 791	128	1.00 209	9.99 786	19	1	12.5	12.3
42	8.99 704	126	8.99 919	127	1.00 081	9.99 785	18	2	25.0	24.6
43	8.99 830	126	9.00 046	128	0.99 954	9.99 783	17	3	37.5	36.9
44	8.99 956	126	9.00 174	127	0.99 826	9.99 782	16	4	50.0	49.2
45	9.00 082	125	9.00 301	126	0.99 699	9.99 781	15	5	62.5	61.5
46	9.00 207	125	9.00 427	126	0.99 573	9.99 780	14	6	75.0	73.8
47	9.00 332	124	9.00 553	126	0.99 447	9.99 778	13	7	87.5	86.1
48	9.00 456	125	9.00 679	126	0.99 321	9.99 777	12	8	100.0	98.4
49	9.00 581	123	9.00 805	125	0.99 195	9.99 776	11	9	112.5	110.7
50	9.00 704	124	9.00 930	125	0.99 070	9.99 775	10	121	120	1
51	9.00 828	123	9.01 055	124	0.98 945	9.99 773	9	1	12.1	12.0
52	9.00 951	123	9.01 179	124	0.98 821	9.99 772	8	2	24.2	24.0
53	9.01 074	122	9.01 303	124	0.98 697	9.99 771	7	3	36.3	36.0
54	9.01 196	122	9.01 427	123	0.98 573	9.99 769	6	4	48.4	48.0
55	9.01 318	122	9.01 550	123	0.98 450	9.99 768	5	5	60.5	60.0
56	9.01 440	121	9.01 673	123	0.98 327	9.99 767	4	6	72.6	72.0
57	9.01 561	121	9.01 796	122	0.98 204	9.99 765	3	7	84.7	84.0
58	9.01 682	121	9.01 918	122	0.98 082	9.99 764	2	8	96.8	96.0
59	9.01 803	120	9.02 040	122	0.97 960	9.99 763	1	9	108.9	108.0
60	9.01 923		9.02 162		00.97 838	9.99 761	0			
	L SIN	D	L TAN	CD	L COT	L COS		354°... 174°...		
	L COS		L COT		L TAN	L SIN		264°... 84°...		

6°... 186°		L SIN		L TAN		L COT	L COS		PROP. PTS			
96°... 276°		L COS	D	L COT	CD	L TAN	L SIN					
	0	9.01 923	120	9.02 162	121	0.97 838	9.99 761	60		121	120	119
	1	9.02 043	120	9.02 283	121	0.97 717	9.99 760	59	1	12.1	12.0	11.9
	2	9.02 163	120	9.02 404	121	0.97 596	9.99 759	58	2	24.2	24.0	23.8
	3	9.02 283	119	9.02 525	120	0.97 475	9.99 757	57	3	36.3	36.0	35.7
	4	9.02 402	118	9.02 645	121	0.97 355	9.99 756	56	4	48.4	48.0	47.6
	5	9.02 520	119	9.02 766	119	0.97 234	9.99 755	55	5	60.5	60.0	59.5
	6	9.02 639	118	9.02 885	120	0.97 115	9.99 753	54	6	72.6	72.0	71.4
	7	9.02 757	117	9.03 005	119	0.96 995	9.99 752	53	7	84.7	84.0	83.3
	8	9.02 874	118	9.03 124	118	0.96 876	9.99 751	52	8	96.8	96.0	95.2
	9	9.02 992	117	9.03 242	119	0.96 758	9.99 749	51	9	108.9	108.0	107.1
	10	9.03 109	117	9.03 361	118	0.96 639	9.99 748	50		118	117	116
	11	9.03 226	116	9.03 479	118	0.96 521	9.99 747	49	1	11.8	11.7	11.6
	12	9.03 342	116	9.03 597	117	0.96 403	9.99 745	48	2	23.6	23.4	23.2
	13	9.03 458	116	9.03 714	118	0.96 286	9.99 744	47	3	35.4	35.1	34.8
	14	9.03 574	116	9.03 832	116	0.96 168	9.99 742	46	4	47.2	46.8	46.4
	15	9.03 690	115	9.03 948	117	0.96 052	9.99 741	45	5	59.0	58.5	58.0
	16	9.03 805	115	9.04 065	116	0.95 935	9.99 740	44	6	70.8	70.2	69.6
	17	9.03 920	114	9.04 181	116	0.95 819	9.99 738	43	7	82.6	81.9	81.2
	18	9.04 034	115	9.04 297	116	0.95 703	9.99 737	42	8	94.4	93.6	92.8
	19	9.04 149	113	9.04 413	115	0.95 587	9.99 736	41	9	106.2	105.3	104.4
	20	9.04 262	114	9.04 528	115	0.95 472	9.99 734	40		115	114	113
	21	9.04 376	114	9.04 643	115	0.95 357	9.99 733	39	1	11.5	11.4	11.3
	22	9.04 490	113	9.04 758	115	0.95 242	9.99 731	38	2	23.0	22.8	22.6
	23	9.04 603	112	9.04 873	114	0.95 127	9.99 730	37	3	34.5	34.2	33.9
	24	9.04 715	113	9.04 987	114	0.95 013	9.99 728	36	4	46.0	45.6	45.2
	25	9.04 828	112	9.05 101	113	0.94 899	9.99 727	35	5	57.5	57.0	56.5
	26	9.04 940	112	9.05 214	114	0.94 786	9.99 726	34	6	69.0	68.4	67.8
	27	9.05 052	112	9.05 328	113	0.94 672	9.99 724	33	7	80.5	79.8	79.1
	28	9.05 164	111	9.05 441	112	0.94 559	9.99 723	32	8	92.0	91.2	90.4
	29	9.05 275	111	9.05 553	113	0.94 447	9.99 721	31	9	103.5	102.6	101.7
	30	9.05 386	111	9.05 666	112	0.94 334	9.99 720	30		112	111	110
	31	9.05 497	110	9.05 778	112	0.94 222	9.99 718	29	1	11.2	11.1	11.0
	32	9.05 607	110	9.05 890	112	0.94 110	9.99 717	28	2	22.4	22.2	22.0
	33	9.05 717	110	9.06 002	111	0.93 998	9.99 716	27	3	33.6	33.3	33.0
	34	9.05 827	110	9.06 113	111	0.93 887	9.99 714	26	4	44.8	44.4	44.0
	35	9.05 937	109	9.06 224	111	0.93 776	9.99 713	25	5	56.0	55.5	55.0
	36	9.06 046	109	9.06 335	110	0.93 665	9.99 711	24	6	67.2	66.6	66.0
	37	9.06 155	109	9.06 445	111	0.93 555	9.99 710	23	7	78.4	77.7	77.0
	38	9.06 264	108	9.06 556	110	0.93 444	9.99 708	22	8	89.6	88.8	88.0
	39	9.06 372	109	9.06 666	109	0.93 334	9.99 707	21	9	100.8	99.9	99.0
	40	9.06 481	108	9.06 775	110	0.93 225	9.99 705	20		109	108	107
	41	9.06 589	107	9.06 885	109	0.93 115	9.99 704	19	1	10.9	10.8	10.7
	42	9.06 696	108	9.06 994	109	0.93 006	9.99 702	18	2	21.8	21.6	21.4
	43	9.06 804	107	9.07 103	108	0.92 897	9.99 701	17	3	32.7	32.4	32.1
	44	9.06 911	107	9.07 211	109	0.92 789	9.99 699	16	4	43.6	43.2	42.8
	45	9.07 018	106	9.07 320	108	0.92 680	9.99 698	15	5	54.5	54.0	53.5
	46	9.07 124	107	9.07 428	108	0.92 572	9.99 696	14	6	65.4	64.8	64.2
	47	9.07 231	106	9.07 536	107	0.92 464	9.99 695	13	7	76.3	75.6	74.9
	48	9.07 337	105	9.07 643	108	0.92 357	9.99 693	12	8	87.2	86.4	85.6
	49	9.07 442	106	9.07 751	107	0.92 249	9.99 692	11	9	98.1	97.2	96.3
	50	9.07 548	105	9.07 858	106	0.92 142	9.99 690	10		106	105	104
	51	9.07 653	105	9.07 964	107	0.92 036	9.99 689	9	1	10.6	10.5	10.4
	52	9.07 758	105	9.08 071	106	0.91 929	9.99 687	8	2	21.2	21.0	20.8
	53	9.07 863	105	9.08 177	106	0.91 823	9.99 686	7	3	31.8	31.5	31.2
	54	9.07 968	104	9.08 283	106	0.91 717	9.99 684	6	4	42.4	42.0	41.6
	55	9.08 072	104	9.08 389	106	0.91 611	9.99 683	5	5	53.0	52.5	52.0
	56	9.08 176	104	9.08 495	105	0.91 505	9.99 681	4	6	63.6	63.0	62.4
	57	9.08 280	103	9.08 600	105	0.91 400	9.99 680	3	7	74.2	73.5	72.8
	58	9.08 383	103	9.08 706	105	0.91 295	9.99 678	2	8	84.8	84.0	83.2
	59	9.08 486	103	9.08 810	104	0.91 190	9.99 677	1	9	95.4	94.5	93.6
	60	9.08 589		9.08 914		0.91 086	9.99 675	0				
		L SIN	D	L TAN	CD	L COT	L COS		353°... 173°			
		L COS		L COT		L TAN	L SIN		263°... 83°			

7°—, 187°—		L SIN		L TAN		L COT	L COS		PROP. PTS.			
97°—, 277°—		L COS	D	L COT	CD	L TAN	L SIN					
	0	9.08 589	103	9.08 914	105	0.91 086	9.99 675	60		105	104	103
	1	9.08 692	103	9.09 019	104	0.90 981	9.99 674	59	1	10.5	10.4	10.3
	2	9.08 795	102	9.09 123	104	0.90 877	9.99 672	58	2	21.0	20.8	20.6
	3	9.08 897	102	9.09 227	103	0.90 773	9.99 670	57	3	31.5	31.2	30.9
	4	9.08 999	102	9.09 330	104	0.90 670	9.99 669	56	4	42.0	41.6	41.2
	5	9.09 101	101	9.09 434	103	0.90 566	9.99 667	55	5	52.5	52.0	51.5
	6	9.09 202	102	9.09 537	103	0.90 463	9.99 666	54	6	63.0	62.4	61.8
	7	9.09 304	101	9.09 640	102	0.90 360	9.99 664	53	7	73.5	72.8	72.1
	8	9.09 405	101	9.09 742	103	0.90 258	9.99 663	52	8	84.0	83.2	82.4
	9	9.09 506	100	9.09 845	102	0.90 155	9.99 661	51	9	94.5	93.6	92.7
	10	9.09 606	101	9.09 947	102	0.90 053	9.99 659	50		102	101	100
	11	9.09 707	100	9.10 049	101	0.89 951	9.99 658	49	1	10.2	10.1	10.0
	12	9.09 807	100	9.10 150	102	0.89 850	9.99 656	48	2	20.4	20.2	20.0
	13	9.09 907	99	9.10 252	101	0.89 748	9.99 655	47	3	30.6	30.3	30.0
	14	9.10 006	100	9.10 353	101	0.89 647	9.99 653	46	4	40.8	40.4	40.0
	15	9.10 106	99	9.10 454	101	0.89 546	9.99 651	45	5	51.0	50.5	50.0
	16	9.10 205	99	9.10 555	101	0.89 445	9.99 650	44	6	61.2	60.6	60.0
	17	9.10 304	98	9.10 656	100	0.89 344	9.99 648	43	7	71.4	70.7	70.0
	18	9.10 402	99	9.10 756	100	0.89 244	9.99 647	42	8	81.6	80.8	80.0
	19	9.10 501	98	9.10 856	100	0.89 144	9.99 645	41	9	91.8	90.9	90.0
	20	9.10 599	98	9.10 956	100	0.89 044	9.99 643	40		99	98	
	21	9.10 697	98	9.11 056	99	0.88 944	9.99 642	39	1	9.9	9.8	
	22	9.10 795	98	9.11 155	99	0.88 845	9.99 640	38	2	19.8	19.6	
	23	9.10 893	97	9.11 254	99	0.88 746	9.99 638	37	3	29.7	29.4	
	24	9.10 990	97	9.11 353	99	0.88 647	9.99 637	36	4	39.6	39.2	
	25	9.11 087	97	9.11 452	99	0.88 548	9.99 635	35	5	49.5	49.0	
	26	9.11 184	97	9.11 551	98	0.88 449	9.99 633	34	6	59.4	58.8	
	27	9.11 281	96	9.11 649	98	0.88 351	9.99 632	33	7	69.3	68.6	
	28	9.11 377	97	9.11 747	98	0.88 253	9.99 630	32	8	79.2	78.4	
	29	9.11 474	96	9.11 845	98	0.88 155	9.99 629	31	9	89.1	88.2	
	30	9.11 570	96	9.11 943	97	0.88 057	9.99 627	30		97	96	95
	31	9.11 666	95	9.12 040	98	0.87 960	9.99 625	29	1	9.7	9.6	9.5
	32	9.11 761	96	9.12 138	97	0.87 862	9.99 624	28	2	19.4	19.2	19.0
	33	9.11 857	95	9.12 235	97	0.87 765	9.99 622	27	3	29.1	28.2	28.5
	34	9.11 952	95	9.12 332	96	0.87 668	9.99 620	26	4	38.8	38.4	38.0
	35	9.12 047	95	9.12 428	97	0.87 572	9.99 618	25	5	48.5	48.0	47.5
	36	9.12 142	94	9.12 525	96	0.87 475	9.99 617	24	6	58.2	57.6	57.0
	37	9.12 236	95	9.12 621	96	0.87 379	9.99 615	23	7	67.9	67.2	66.5
	38	9.12 331	94	9.12 717	96	0.87 283	9.99 613	22	8	77.6	76.8	76.0
	39	9.12 425	94	9.12 813	96	0.87 187	9.99 612	21	9	87.3	86.4	85.5
	40	9.12 519	93	9.12 909	95	0.87 091	9.99 610	20		94	93	92
	41	9.12 612	94	9.13 004	95	0.86 996	9.99 608	19	1	9.4	9.3	9.2
	42	9.12 706	93	9.13 099	95	0.86 901	9.99 607	18	2	18.8	18.6	18.4
	43	9.12 799	93	9.13 194	95	0.86 806	9.99 605	17	3	28.2	27.9	27.6
	44	9.12 892	93	9.13 289	95	0.86 711	9.99 603	16	4	37.6	37.2	36.8
	45	9.12 985	93	9.13 384	94	0.86 616	9.99 601	15	5	47.0	46.5	46.0
	46	9.13 078	93	9.13 478	95	0.86 522	9.99 600	14	6	56.4	55.8	55.2
	47	9.13 171	92	9.13 573	94	0.86 427	9.99 598	13	7	65.8	65.1	64.4
	48	9.13 263	92	9.13 667	94	0.86 333	9.99 596	12	8	75.2	74.4	73.6
	49	9.13 355	92	9.13 761	93	0.86 239	9.99 595	11	9	84.6	83.7	82.8
	50	9.13 447	92	9.13 854	94	0.86 146	9.99 593	10		91	90	2
	51	9.13 539	91	9.13 948	93	0.86 052	9.99 591	9	1	9.1	9.0	0.2
	52	9.13 630	92	9.14 041	93	0.85 959	9.99 589	8	2	18.2	18.0	0.4
	53	9.13 722	91	9.14 134	93	0.85 866	9.99 588	7	3	27.3	27.0	0.6
	54	9.13 813	91	9.14 227	93	0.85 773	9.99 586	6	4	36.4	36.0	0.8
	55	9.13 904	90	9.14 320	92	0.85 680	9.99 584	5	5	45.5	45.0	1.0
	56	9.13 994	91	9.14 412	92	0.85 588	9.99 582	4	6	54.6	54.0	1.2
	57	9.14 085	90	9.14 504	93	0.85 496	9.99 581	3	7	63.7	63.0	1.4
	58	9.14 175	91	9.14 597	91	0.85 403	9.99 579	2	8	72.8	72.0	1.6
	59	9.14 266	90	9.14 688	92	0.85 312	9.99 577	1	9	81.9	81.0	1.8
	60	9.14 356		9.14 780		0.85 220	9.99 575	0				
		L SIN	D	L TAN	CD	L COT	L COS		352°—, 172°—			
		L COS		L COT		L TAN	L SIN		262°—, 82°—			

8°... 188°	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
98°... 278°	L COS		L COT		L TAN	L SIN	
0	9.14 356	89	9.14 780	92	0.85 220	9.99 575	60
1	9.14 445	90	9.14 872	91	0.85 128	9.99 574	59
2	9.14 535	89	9.14 963	91	0.85 037	9.99 572	58
3	9.14 624	89	9.15 054	91	0.84 946	9.99 570	57
4	9.14 714	89	9.15 145	91	0.84 855	9.99 568	56
5	9.14 803	88	9.15 236	91	0.84 764	9.99 566	55
6	9.14 891	89	9.15 327	90	0.84 673	9.99 565	54
7	9.14 980	89	9.15 417	91	0.84 583	9.99 563	53
8	9.15 069	88	9.15 508	90	0.84 492	9.99 561	52
9	9.15 157	88	9.15 598	90	0.84 402	9.99 559	51
10	9.15 245	88	9.15 688	89	0.84 312	9.99 557	50
11	9.15 333	88	9.15 777	90	0.84 223	9.99 556	49
12	9.15 421	87	9.15 867	89	0.84 133	9.99 554	48
13	9.15 508	88	9.15 956	90	0.84 044	9.99 552	47
14	9.15 596	87	9.16 046	89	0.83 954	9.99 550	46
15	9.15 683	87	9.16 135	89	0.83 865	9.99 548	45
16	9.15 770	87	9.16 224	88	0.83 776	9.99 546	44
17	9.15 857	87	9.16 312	89	0.83 688	9.99 545	43
18	9.15 944	86	9.16 401	88	0.83 599	9.99 543	42
19	9.16 030	86	9.16 489	88	0.83 511	9.99 541	41
20	9.16 116	87	9.16 577	88	0.83 423	9.99 539	40
21	9.16 203	86	9.16 665	88	0.83 335	9.99 537	39
22	9.16 289	85	9.16 753	88	0.83 247	9.99 535	38
23	9.16 374	86	9.16 841	87	0.83 159	9.99 533	37
24	9.16 460	85	9.16 928	88	0.83 072	9.99 532	36
25	9.16 545	86	9.17 016	87	0.82 984	9.99 530	35
26	9.16 631	85	9.17 103	87	0.82 897	9.99 528	34
27	9.16 716	85	9.17 190	87	0.82 810	9.99 526	33
28	9.16 801	85	9.17 277	86	0.82 723	9.99 524	32
29	9.16 886	84	9.17 363	87	0.82 637	9.99 522	31
30	9.16 970	85	9.17 450	86	0.82 550	9.99 520	30
31	9.17 055	84	9.17 536	86	0.82 464	9.99 518	29
32	9.17 139	84	9.17 622	86	0.82 378	9.99 517	28
33	9.17 223	84	9.17 708	86	0.82 292	9.99 515	27
34	9.17 307	84	9.17 794	86	0.82 206	9.99 513	26
35	9.17 391	83	9.17 880	85	0.82 120	9.99 511	25
36	9.17 474	84	9.17 965	86	0.82 035	9.99 509	24
37	9.17 558	83	9.18 051	85	0.81 949	9.99 507	23
38	9.17 641	83	9.18 136	85	0.81 864	9.99 505	22
39	9.17 724	83	9.18 221	85	0.81 779	9.99 503	21
40	9.17 807	83	9.18 306	85	0.81 694	9.99 501	20
41	9.17 890	83	9.18 391	84	0.81 609	9.99 499	19
42	9.17 973	82	9.18 475	85	0.81 525	9.99 497	18
43	9.18 055	82	9.18 560	84	0.81 440	9.99 495	17
44	9.18 137	83	9.18 644	84	0.81 356	9.99 494	16
45	9.18 220	82	9.18 728	84	0.81 272	9.99 492	15
46	9.18 302	81	9.18 812	84	0.81 188	9.99 490	14
47	9.18 383	82	9.18 869	83	0.81 104	9.99 488	13
48	9.18 465	82	9.18 979	84	0.81 021	9.99 486	12
49	9.18 547	81	9.19 063	83	0.80 937	9.99 484	11
50	9.18 628	81	9.19 146	83	0.80 854	9.99 482	10
51	9.18 709	81	9.19 229	83	0.80 771	9.99 480	9
52	9.18 790	81	9.19 342	83	0.80 688	9.99 478	8
53	9.18 871	81	9.19 395	83	0.80 605	9.99 476	7
54	9.18 952	81	9.19 478	83	0.80 522	9.99 474	6
55	9.19 033	80	9.19 561	82	0.80 439	9.99 472	5
56	9.19 113	80	9.19 643	82	0.80 357	9.99 470	4
57	9.19 193	80	9.19 725	82	0.80 275	9.99 468	3
58	9.19 273	80	9.19 807	82	0.80 193	9.99 466	2
59	9.19 353	80	9.19 889	82	0.80 111	9.99 464	1
60	9.19 433		9.19 971		0.80 029	9.99 462	0
	L SIN	D	L TAN	CD	L COT	L COS	351°... 171°
	L COS		L COT		L TAN	L SIN	261°... 81°

9°—, 189°—	L SIN	D	L TAN	CD	L COT	L COS		PROP. PTS.		
99°—, 279°—	L COS		L COT		L TAN	L SIN				
0	9.19 433	80	9.19 971	82	0.80 029	9.99 462	60			
1	9.19 513	79	9.20 053	81	0.79 947	9.99 460	59			
2	9.19 592	80	9.20 134	82	0.79 866	9.99 458	58	1	8.2	8.1
3	9.19 672	79	9.20 216	81	0.79 784	9.99 456	57	2	18.4	18.2
4	9.19 751	79	9.20 297	81	0.79 703	9.99 454	56	3	24.8	24.3
								4	32.8	32.4
5	8.19 830	79	9.20 378	81	0.79 822	9.99 452	55	5	41.0	40.6
6	9.19 909	79	9.20 459	81	0.78 541	9.99 450	54	8	48.2	48.8
7	9.19 988	79	9.20 540	81	0.79 460	9.99 448	53	7	67.4	66.7
8	9.20 067	78	9.20 621	80	0.79 379	9.99 446	52	8	86.8	84.8
9	9.20 145	78	9.20 701	81	0.79 299	9.99 444	51	9	73.8	72.8
10	9.20 223	79	9.20 782	80	0.78 218	9.99 442	50		79	78
11	9.20 302	78	9.20 862	80	0.79 138	9.99 440	49			
12	9.20 380	78	9.20 942	80	0.79 058	9.99 438	48	1	7.9	7.8
13	9.20 458	77	9.21 022	80	0.78 978	9.99 436	47	2	15.8	15.8
14	9.20 535	78	9.21 102	80	0.78 898	9.99 434	46	3	23.7	23.4
								4	31.8	31.2
15	9.20 613	78	9.21 182	79	0.78 818	9.99 432	45	6	39.5	39.0
16	9.20 691	77	9.21 281	80	0.78 739	9.99 429	44	6	47.4	48.8
17	9.20 768	77	9.21 341	79	0.78 659	9.99 427	43	7	55.3	54.8
18	9.20 845	77	9.21 420	79	0.78 580	9.99 425	42	8	63.2	62.4
19	9.20 922	77	9.21 499	79	0.78 501	9.99 423	41	9	71.1	70.2
20	9.20 999	77	9.21 578	79	0.78 422	9.99 421	40		77	78
21	9.21 076	77	9.21 657	79	0.78 343	9.99 419	39			
22	9.21 153	76	9.21 736	78	0.78 264	9.99 417	38	1	7.7	7.6
23	9.21 229	77	9.21 814	79	0.78 186	9.99 415	37	2	15.4	15.2
24	9.21 306	76	9.21 893	78	0.78 107	9.99 413	36	3	23.1	22.8
								4	30.8	30.4
25	9.21 382	76	9.21 971	78	0.78 029	9.99 411	35	5	38.5	38.0
26	9.21 458	76	9.22 049	78	0.77 951	9.99 409	34	6	48.2	45.6
27	9.21 534	76	9.22 127	78	0.77 873	9.99 407	33	7	53.9	53.2
28	9.21 610	75	9.22 205	78	0.77 795	9.99 404	32	8	81.6	60.8
29	9.21 685	76	9.22 283	78	0.77 717	9.99 402	31	9	69.3	68.4
30	9.21 761	75	9.22 381	77	0.77 639	9.99 400	30		75	74
31	9.21 836	76	9.22 438	78	0.77 562	9.99 398	29			
32	9.21 912	75	9.22 518	77	0.77 484	9.99 396	28	1	7.6	7.4
33	9.21 987	75	9.22 593	77	0.77 407	9.99 394	27	2	15.0	14.8
34	9.22 062	75	9.22 670	77	0.77 330	9.99 392	26	3	22.5	22.2
								4	30.0	29.8
35	9.22 137	74	9.22 747	77	0.77 263	9.99 390	25	5	37.5	37.0
36	9.22 211	75	9.22 824	77	0.77 176	9.99 388	24	6	45.0	44.4
37	9.22 286	75	9.22 901	76	0.77 099	9.99 385	23	7	52.5	51.8
38	9.22 361	74	9.22 977	76	0.77 023	9.99 383	22	8	60.0	59.2
39	9.22 435	74	9.23 054	76	0.76 945	9.99 381	21	9	87.6	56.6
40	9.22 509	74	9.23 130	76	0.76 870	9.99 379	20		73	72
41	9.22 583	74	9.23 206	77	0.76 794	9.99 377	19			
42	9.22 657	74	9.23 283	76	0.76 717	9.99 375	18	1	7.3	7.2
43	9.22 731	74	9.23 359	76	0.76 641	9.99 372	17	2	14.6	14.4
44	9.22 805	73	9.23 435	75	0.76 565	9.99 370	16	3	21.9	21.6
								4	29.2	28.8
45	9.22 878	74	9.23 510	76	0.76 490	9.99 368	15	5	36.5	36.0
46	9.22 952	73	9.23 586	75	0.76 414	9.99 366	14	6	43.8	43.2
47	9.23 025	73	9.23 661	76	0.76 339	9.99 364	13	7	51.1	50.4
48	9.23 098	73	9.23 737	75	0.76 263	9.99 362	12	8	58.4	57.8
49	9.23 171	73	9.23 812	75	0.76 188	9.99 359	11	9	65.7	64.8
50	9.23 244	73	9.23 887	75	0.76 113	9.99 357	10		71	3
51	9.23 317	73	9.23 962	75	0.76 038	9.99 355	9			2
52	9.23 390	72	9.24 037	75	0.75 963	9.99 353	8	1	7.1	0.3
53	9.23 462	73	9.24 112	74	0.75 888	9.99 351	7	2	14.2	0.6
54	9.23 535	72	9.24 186	75	0.75 814	9.99 348	6	3	21.3	0.9
								4	28.4	1.2
55	9.23 607	72	9.24 261	74	0.75 739	9.99 348	5	6	35.5	1.5
58	9.23 679	73	9.24 335	75	0.75 665	9.99 344	4	8	42.6	1.8
57	9.23 752	71	9.24 410	74	0.75 590	9.99 342	3	7	49.7	2.1
58	9.23 823	72	9.24 484	74	0.75 518	9.99 340	2	8	56.8	2.4
59	9.23 895	72	9.24 558	74	0.75 442	9.99 337	1	9	63.9	2.7
60	9.23 967		9.24 632		0.75 368	9.99 335	0			
	L SIN	D	L TAN	CD	L COT	L COS		350°—, 170°—		
	L COS		L COT		L TAN	L SIN		260°—, 80°—		

10°... 190°	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
100°... 280°	L COS		L COT		L TAN	L SIN	
0	9.23 967	72	9.24 632	74	0.75 368	9.99 335	60
1	9.24 039	71	9.24 706	73	0.75 294	9.99 333	59
2	9.24 110	71	9.24 779	74	0.75 221	9.99 331	58
3	9.24 181	72	9.24 853	73	0.75 147	9.99 328	57
4	9.24 253	71	9.24 926	74	0.75 074	9.99 326	56
5	9.24 324	71	9.25 000	73	0.75 000	9.99 324	55
6	9.24 395	71	9.25 073	73	0.74 927	9.99 322	54
7	9.24 466	70	9.25 146	73	0.74 854	9.99 319	53
8	9.24 536	71	9.25 219	73	0.74 781	9.99 317	52
9	9.24 607	70	9.25 292	73	0.74 708	9.99 315	51
10	9.24 677	71	9.25 365	72	0.74 635	9.99 313	50
11	9.24 748	70	9.25 437	73	0.74 563	9.99 310	49
12	9.24 818	70	9.25 510	72	0.74 490	9.99 308	48
13	9.24 888	70	9.25 582	73	0.74 418	9.99 306	47
14	9.24 958	70	9.25 655	72	0.74 345	9.99 304	46
15	9.25 028	70	9.25 727	72	0.74 273	9.99 301	45
16	9.25 098	70	9.25 799	72	0.74 201	9.99 299	44
17	9.25 168	69	9.25 871	72	0.74 129	9.99 297	43
18	9.25 237	70	9.25 943	72	0.74 057	9.99 294	42
19	9.25 307	69	9.26 015	71	0.73 985	9.99 292	41
20	9.25 376	69	9.26 086	72	0.73 914	9.99 290	40
21	9.25 445	69	9.26 158	71	0.73 842	9.99 288	39
22	9.25 514	69	9.26 229	72	0.73 771	9.99 285	38
23	9.25 583	69	9.26 301	71	0.73 699	9.99 283	37
24	9.25 652	69	9.26 372	71	0.73 628	9.99 281	36
25	9.25 721	69	9.26 443	71	0.73 557	9.99 278	35
26	9.25 790	68	9.26 514	71	0.73 486	9.99 276	34
27	9.25 858	69	9.26 585	70	0.73 415	9.99 274	33
28	9.25 927	68	9.26 655	71	0.73 345	9.99 271	32
29	9.25 995	68	9.26 726	71	0.73 274	9.99 269	31
30	9.26 063	68	9.26 797	70	0.73 203	9.99 267	30
31	9.26 131	68	9.26 867	70	0.73 133	9.99 264	29
32	9.26 199	68	9.26 937	71	0.73 063	9.99 262	28
33	9.26 267	68	9.27 008	70	0.72 992	9.99 260	27
34	9.26 335	68	9.27 078	70	0.72 922	9.99 257	26
35	9.26 403	67	9.27 148	70	0.72 852	9.99 255	25
36	9.26 470	68	9.27 218	70	0.72 782	9.99 252	24
37	9.26 538	67	9.27 288	69	0.72 712	9.99 250	23
38	9.26 605	67	9.27 357	70	0.72 643	9.99 248	22
39	9.26 672	67	9.27 427	69	0.72 573	9.99 245	21
40	9.26 739	67	9.27 496	70	0.72 504	9.99 243	20
41	9.26 806	67	9.27 566	69	0.72 434	9.99 241	19
42	9.26 873	67	9.27 635	69	0.72 365	9.99 238	18
43	9.26 940	67	9.27 704	69	0.72 296	9.99 236	17
44	9.27 007	66	9.27 773	69	0.72 227	9.99 233	16
45	9.27 073	67	9.27 842	69	0.72 158	9.99 231	15
46	9.27 140	66	9.27 911	69	0.72 089	9.99 229	14
47	9.27 206	67	9.27 980	69	0.72 020	9.99 226	13
48	9.27 273	66	9.28 049	68	0.71 951	9.99 224	12
49	9.27 339	66	9.28 117	69	0.71 883	9.99 221	11
50	9.27 405	66	9.28 186	68	0.71 814	9.99 219	10
51	9.27 471	66	9.28 254	69	0.71 746	9.99 217	9
52	9.27 537	65	9.28 323	68	0.71 677	9.99 214	8
53	9.27 602	66	9.28 391	68	0.71 609	9.99 212	7
54	9.27 668	66	9.28 459	68	0.71 541	9.99 209	6
55	9.27 734	65	9.28 527	68	0.71 473	9.99 207	5
56	9.27 799	65	9.28 595	67	0.71 405	9.99 204	4
57	9.27 864	66	9.28 662	68	0.71 338	9.99 202	3
58	9.27 930	65	9.28 730	68	0.71 270	9.99 200	2
59	9.27 995	65	9.28 798	67	0.71 202	9.99 197	1
60	9.28 060		9.28 865		0.71 135	9.99 195	0
	L SIN	D	L TAN	CD	L COT	L COS	349°... 169°...
	L COS		L COT		L TAN	L SIN	259°... 79°...

11°... 191°	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
101°... 261°	L COS		L COT		L TAN	L SIN	
0	9.28 060	65	9.28 865	68	0.71 135	9.99 195	60
1	9.28 125	65	9.28 933	67	0.71 067	9.99 192	59
2	9.28 190	64	9.29 000	67	0.71 000	9.99 190	58
3	9.28 294	65	9.29 867	67	0.70 933	9.99 187	57
4	9.28 319	65	9.29 134	67	0.70 866	9.99 185	56
5	9.28 384	64	9.29 201	67	0.70 799	9.99 182	55
6	9.28 448	64	9.29 268	67	0.70 732	9.99 180	54
7	9.28 512	65	9.29 335	67	0.70 665	9.99 177	53
8	9.28 577	64	9.29 402	66	0.70 598	9.99 175	52
9	9.28 641	64	9.29 468	67	0.70 532	9.99 172	51
10	9.28 705	64	9.29 535	66	0.70 465	9.99 170	50
11	9.28 769	64	9.29 601	67	0.70 399	9.99 167	49
12	9.28 833	63	9.29 668	66	0.70 332	9.99 165	48
13	9.28 896	64	9.29 734	66	0.70 266	9.99 162	47
14	9.28 960	64	9.29 800	66	0.70 200	9.99 160	46
15	9.29 024	63	9.29 866	66	0.70 134	9.99 157	45
16	9.29 087	63	9.29 932	66	0.70 068	9.99 155	44
17	9.29 150	64	9.29 998	66	0.70 002	9.99 152	43
18	9.29 214	63	9.30 064	66	0.69 936	9.99 150	42
19	9.29 277	63	9.30 130	65	0.69 870	9.99 147	41
20	9.29 340	63	9.30 195	66	0.69 805	9.99 145	40
21	9.29 403	63	9.30 261	65	0.69 739	9.99 142	39
22	9.29 466	63	9.30 326	65	0.69 674	9.99 140	38
23	9.29 529	62	9.30 391	66	0.69 609	9.99 137	37
24	9.29 591	63	9.30 457	65	0.69 543	9.99 135	36
25	9.29 654	62	9.30 522	65	0.69 478	9.99 132	35
26	9.29 716	63	9.30 587	65	0.69 413	9.99 130	34
27	9.29 779	62	9.30 652	65	0.69 348	9.99 127	33
28	9.29 841	62	9.30 717	65	0.69 283	9.99 124	32
29	9.29 903	63	9.30 782	64	0.69 218	9.99 122	31
30	9.29 966	62	9.30 846	65	0.69 154	9.99 119	30
31	9.30 028	62	9.30 911	64	0.69 089	9.99 117	29
32	9.30 090	61	9.30 975	65	0.69 025	9.99 114	28
33	9.30 151	62	9.31 040	64	0.68 960	9.99 112	27
34	9.30 213	62	9.31 104	64	0.68 896	9.99 109	26
35	9.30 275	61	9.31 168	65	0.68 832	9.99 106	25
36	9.30 336	62	9.31 233	64	0.68 767	9.99 104	24
37	9.30 398	61	9.31 297	64	0.68 703	9.99 101	23
38	9.30 459	62	9.31 361	64	0.68 639	9.99 099	22
39	9.30 521	61	9.31 425	64	0.68 575	9.99 099	21
40	9.30 582	61	9.31 489	63	0.68 511	9.99 093	20
41	9.30 643	61	9.31 552	64	0.68 448	9.99 091	19
42	9.30 704	61	9.31 616	63	0.68 384	9.99 088	18
43	9.30 765	61	9.31 679	64	0.68 321	9.99 086	17
44	9.30 826	61	9.31 743	63	0.68 257	9.99 083	16
45	9.30 887	60	9.31 806	64	0.68 194	9.99 080	15
46	9.30 947	61	9.31 870	63	0.68 130	9.99 078	14
47	9.31 008	60	9.31 933	63	0.68 067	9.99 075	13
48	9.31 068	61	9.31 996	63	0.68 004	9.99 072	12
49	9.31 129	60	9.32 059	63	0.67 941	9.99 070	11
50	9.31 189	61	9.32 122	63	0.67 878	9.99 067	10
51	9.31 250	60	9.32 185	63	0.67 815	9.99 064	9
52	9.31 310	60	9.32 248	63	0.67 752	9.99 062	8
53	9.31 370	60	9.32 311	62	0.67 689	9.99 059	7
54	9.31 430	60	9.32 373	63	0.67 627	9.99 056	6
55	9.31 490	59	9.32 436	62	0.67 564	9.99 054	5
56	9.31 549	60	9.32 498	63	0.67 502	9.99 051	4
57	9.31 609	60	9.32 561	62	0.67 439	9.99 048	3
58	9.31 669	59	9.32 623	62	0.67 377	9.99 046	2
59	9.31 728	60	9.32 685	62	0.67 315	9.99 043	1
60	9.31 788		9.32 747		0.67 253	9.99 040	0
	L SIN	D	L TAN	CD	L COT	L COS	348°... 168°
	L COS		L COT		L TAN	L SIN	258°... 78°

12° __, 192° __	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
102° __, 282° __	L COS		L COT		L TAN	L SIN	
0	9.31 788	59	9.32 747	63	0.67 253	9.99 040	60
1	9.31 847	60	9.32 810	62	0.67 190	9.99 038	59
2	9.31 907	59	9.32 872	61	0.67 128	9.99 035	58
3	9.31 966	59	9.32 933	62	0.67 067	9.99 032	57
4	9.32 025	59	9.32 995	62	0.67 005	9.99 030	56
5	9.32 084	59	9.33 057	62	0.66 943	9.99 027	55
6	9.32 143	59	9.33 119	61	0.66 881	9.99 024	54
7	9.32 202	59	9.33 180	62	0.66 820	9.99 022	53
8	9.32 261	58	9.33 242	61	0.66 758	9.99 019	52
9	9.32 319	59	9.33 303	82	0.66 697	9.99 016	51
10	9.32 378	59	9.33 365	61	0.66 635	9.99 013	50
11	9.32 437	58	9.33 426	61	0.66 574	9.99 011	49
12	9.32 495	58	9.33 487	61	0.66 513	9.99 008	48
13	9.32 553	59	9.33 548	61	0.66 452	9.99 005	47
14	9.32 612	58	9.33 609	61	0.66 391	9.99 002	46
15	9.32 670	58	9.33 670	61	0.66 330	9.99 000	45
16	9.32 728	58	9.33 731	61	0.66 269	9.98 997	44
17	9.32 786	58	9.33 792	61	0.66 208	9.98 994	43
18	9.32 844	58	9.33 853	60	0.66 147	9.98 991	42
19	9.32 902	58	9.33 913	61	0.66 087	9.98 989	41
20	9.32 960	58	9.33 974	60	0.66 026	9.98 986	40
21	9.33 018	57	9.34 034	61	0.65 966	9.98 983	39
22	9.33 075	58	9.34 095	60	0.65 905	9.98 980	38
23	9.33 133	57	9.34 155	60	0.65 845	9.98 978	37
24	9.33 190	58	9.34 215	61	0.65 785	9.98 975	36
25	9.33 248	57	9.34 276	60	0.65 724	9.98 972	35
26	9.33 305	57	9.34 336	60	0.65 664	9.98 969	34
27	9.33 362	58	9.34 396	60	0.65 604	9.98 967	33
28	9.33 420	57	9.34 456	60	0.65 544	9.98 964	32
29	9.33 477	57	9.34 516	60	0.65 484	9.98 961	31
30	9.33 534	57	9.34 576	59	0.65 424	9.98 958	30
31	9.33 591	56	9.34 635	60	0.65 365	9.98 955	29
32	9.33 647	57	9.34 695	60	0.65 305	9.98 953	28
33	9.33 704	57	9.34 755	59	0.65 245	9.98 950	27
34	9.33 761	57	9.34 814	60	0.65 186	9.98 947	26
35	9.33 818	56	9.34 874	59	0.65 126	9.98 944	25
36	9.33 874	57	9.34 933	59	0.65 067	9.98 941	24
37	9.33 931	56	9.34 992	59	0.65 008	9.98 938	23
38	9.33 987	56	9.35 051	60	0.64 949	9.98 936	22
39	9.34 043	57	9.35 111	59	0.64 889	9.98 933	21
40	9.34 100	56	9.35 170	59	0.64 830	9.98 930	20
41	9.34 156	56	9.35 229	59	0.64 771	9.98 927	19
42	9.34 212	56	9.35 288	59	0.64 712	9.98 924	18
43	9.34 268	56	9.35 347	58	0.64 653	9.98 921	17
44	9.34 324	56	9.35 405	59	0.64 595	9.98 919	16
45	9.34 380	56	9.35 464	59	0.64 536	9.98 916	15
46	9.34 436	55	9.35 523	58	0.64 477	9.98 913	14
47	9.34 491	56	9.35 581	59	0.64 419	9.98 910	13
48	9.34 547	55	9.35 640	58	0.64 360	9.98 907	12
49	9.34 602	56	9.35 698	59	0.64 302	9.98 904	11
50	9.34 658	55	9.35 757	58	0.64 243	9.98 901	10
51	9.34 713	56	9.35 815	58	0.64 185	9.98 898	9
52	9.34 769	55	9.35 873	58	0.64 127	9.98 896	8
53	9.34 824	55	9.35 931	58	0.64 069	9.98 893	7
54	9.34 879	55	9.35 989	58	0.64 011	9.98 890	6
55	9.34 934	55	9.36 047	58	0.63 953	9.98 887	5
56	9.34 989	55	9.36 105	58	0.63 895	9.98 884	4
57	9.35 044	55	9.36 163	58	0.63 837	9.98 881	3
58	9.35 099	55	9.36 221	58	0.63 779	9.98 878	2
59	9.35 154	55	9.36 279	57	0.63 721	9.98 875	1
60	9.35 209		9.36 336		0.63 664	9.98 872	0
	L SIN	D	L TAN	CD	L COT	L COS	347° __, 167° __
	L COS		L COT		L TAN	L SIN	257° __, 77° __

13°... 193°...	L SIN	D	L TAN	CD	L COT	L COS	PROP. PTS.
103°... 283°...	L COS		L COT		L TAN	L SIN	
0	9.35 209	54	9.36 336	58	0.63 664	9.98 872	60
1	9.35 263	55	9.36 394	58	0.63 606	9.98 869	59
2	9.35 318	55	9.36 452	57	0.63 548	9.98 867	58
3	9.35 373	54	9.36 509	57	0.63 491	9.98 864	57
4	9.35 427	54	9.36 568	58	0.63 434	9.98 861	56
5	9.35 481	55	9.36 624	57	0.63 376	9.98 858	55
6	9.35 536	54	9.36 681	57	0.63 319	9.98 855	54
7	9.35 590	54	9.36 738	57	0.63 262	9.98 852	53
8	9.35 644	54	9.36 795	57	0.63 205	9.98 849	52
9	9.35 698	54	9.36 852	57	0.63 148	9.98 846	51
10	9.35 752	54	9.36 909	57	0.63 091	9.98 843	50
11	9.35 806	54	9.36 966	57	0.63 034	9.98 840	49
12	9.35 860	54	9.37 023	57	0.62 977	9.98 837	48
13	9.35 914	54	9.37 080	57	0.62 920	9.98 834	47
14	9.35 968	54	9.37 137	56	0.62 863	9.98 831	46
15	9.36 022	53	9.37 193	57	0.62 807	9.98 828	45
16	9.36 075	54	9.37 250	56	0.62 750	9.98 825	44
17	9.36 129	53	9.37 306	57	0.62 694	9.98 822	43
18	9.36 182	54	9.37 363	56	0.62 637	9.98 819	42
19	9.36 236	53	9.37 419	57	0.62 581	9.98 816	41
20	9.36 289	53	9.37 476	56	0.62 524	9.98 813	40
21	9.36 342	53	9.37 532	56	0.62 468	9.98 810	39
22	9.36 395	54	9.37 588	56	0.62 412	9.98 807	38
23	9.36 449	53	9.37 644	56	0.62 356	9.98 804	37
24	9.36 502	53	9.37 700	56	0.62 300	9.98 801	36
25	9.36 555	53	9.37 756	56	0.62 244	9.98 798	35
26	9.36 608	52	9.37 812	56	0.62 188	9.98 795	34
27	9.36 660	53	9.37 868	56	0.62 132	9.98 792	33
28	9.36 713	53	9.37 924	56	0.62 076	9.98 789	32
29	9.36 766	53	9.37 980	55	0.62 020	9.98 786	31
30	9.36 819	52	9.38 035	56	0.61 965	9.98 783	30
31	9.36 871	53	9.38 091	56	0.61 909	9.98 780	29
32	9.36 924	52	9.38 147	55	0.61 853	9.98 777	28
33	9.36 976	52	9.38 202	55	0.61 798	9.98 774	27
34	9.37 028	53	9.38 257	56	0.61 743	9.98 771	26
35	9.37 081	52	9.38 313	55	0.61 687	9.98 768	25
36	9.37 133	52	9.38 368	55	0.61 632	9.98 765	24
37	9.37 185	52	9.38 423	56	0.61 577	9.98 762	23
38	9.37 237	52	9.38 479	55	0.61 521	9.98 759	22
39	9.37 289	52	9.38 534	55	0.61 466	9.98 756	21
40	9.37 341	52	9.38 589	55	0.61 411	9.98 753	20
41	9.37 393	52	9.38 644	55	0.61 356	9.98 750	19
42	9.37 445	52	9.38 699	55	0.61 301	9.98 746	18
43	9.37 497	52	9.38 754	54	0.61 246	9.98 743	17
44	9.37 549	51	9.38 808	55	0.61 192	9.98 740	16
45	9.37 600	52	9.38 863	55	0.61 137	9.98 737	15
46	9.37 652	51	9.38 918	54	0.61 082	9.98 734	14
47	9.37 703	52	9.38 972	55	0.61 028	9.98 731	13
48	9.37 755	51	9.39 027	55	0.60 973	9.98 728	12
49	9.37 806	52	9.39 082	54	0.60 918	9.98 725	11
50	9.37 858	51	9.39 136	54	0.60 864	9.98 722	10
51	9.37 909	51	9.39 190	55	0.60 810	9.98 719	9
52	9.37 960	51	9.39 245	54	0.60 755	9.98 715	8
53	9.38 011	51	9.39 299	54	0.60 701	9.98 712	7
54	9.38 062	51	9.39 353	54	0.60 647	9.98 709	6
55	9.38 113	51	9.39 407	54	0.60 593	9.98 706	5
56	9.38 164	51	9.39 461	54	0.60 539	9.98 703	4
57	9.38 215	51	9.39 515	54	0.60 485	9.98 700	3
58	9.38 266	51	9.39 569	54	0.60 431	9.98 697	2
59	9.38 317	51	9.39 623	54	0.60 377	9.98 694	1
60	9.38 368		9.39 677		0.60 323	9.98 690	0
	L SIN	D	L TAN	CD	L COT	L COS	346°... 166°...
	L COS		L COT		L TAN	L SIN	256°... 76°...

14°... 194°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS
104°... 284°...	L COS		L COT		L TAN	L SIN		
0	9.38 368	50	9.39 677	54	0.60 323	9.98 690	3	60
1	9.38 418	51	9.39 731	54	0.60 269	9.98 687	3	59
2	9.38 469	50	9.39 785	53	0.60 215	9.98 684	3	58
3	9.38 519	51	9.39 838	54	0.60 162	9.98 681	3	57
4	9.38 570	50	9.39 892	53	0.60 108	9.98 678	3	56
5	9.38 620	50	9.39 945	54	0.60 055	9.98 675	4	55
6	9.38 670	51	9.39 999	53	0.60 001	9.98 671	3	54
7	9.38 721	50	9.40 052	54	0.59 948	9.98 668	3	53
8	9.38 771	50	9.40 106	53	0.59 894	9.98 665	3	52
9	9.38 821	50	9.40 159	53	0.59 841	9.98 662	3	51
10	9.38 871	50	9.40 212	54	0.59 788	9.98 659	3	50
11	9.38 921	50	9.40 266	53	0.59 734	9.98 656	4	49
12	9.38 971	50	9.40 319	53	0.59 681	9.98 652	3	48
13	9.39 021	50	9.40 372	53	0.59 628	9.98 649	3	47
14	9.39 071	50	9.40 425	53	0.59 575	9.98 646	3	46
15	9.39 121	49	9.40 478	53	0.59 522	9.98 643	3	45
16	9.39 170	50	9.40 531	53	0.59 469	9.98 640	4	44
17	9.39 220	50	9.40 584	52	0.59 416	9.98 636	3	43
18	9.39 270	49	9.40 636	53	0.59 364	9.98 633	3	42
19	9.39 319	50	9.40 689	53	0.59 311	9.98 630	3	41
20	9.39 369	49	9.40 742	53	0.59 258	9.98 627	4	40
21	9.39 418	49	9.40 795	52	0.59 205	9.98 623	3	39
22	9.39 467	50	9.40 847	53	0.59 153	9.98 620	3	38
23	9.39 517	49	9.40 900	52	0.59 100	9.98 617	3	37
24	9.39 566	49	9.40 952	53	0.59 048	9.98 614	4	36
25	9.39 615	49	9.41 005	52	0.58 995	9.98 610	3	35
26	9.39 664	49	9.41 057	52	0.58 943	9.98 607	3	34
27	9.39 713	49	9.41 109	52	0.58 891	9.98 604	3	33
28	9.39 762	49	9.41 161	53	0.58 839	9.98 601	4	32
29	9.39 811	49	9.41 214	52	0.58 786	9.98 597	3	31
30	9.39 860	49	9.41 266	52	0.58 734	9.98 594	3	30
31	9.39 909	49	9.41 318	52	0.58 682	9.98 591	3	29
32	9.39 958	48	9.41 370	52	0.58 630	9.98 588	4	28
33	9.40 006	49	9.41 422	52	0.58 578	9.98 584	3	27
34	9.40 055	48	9.41 474	52	0.58 526	9.98 581	3	26
35	9.40 103	49	9.41 526	52	0.58 474	9.98 578	4	25
36	9.40 152	48	9.41 578	51	0.58 422	9.98 574	3	24
37	9.40 200	49	9.41 629	52	0.58 371	9.98 571	3	23
38	9.40 249	48	9.41 681	52	0.58 319	9.98 568	3	22
39	9.40 297	49	9.41 733	51	0.58 267	9.98 565	4	21
40	9.40 346	48	9.41 784	52	0.58 216	9.98 561	3	20
41	9.40 394	48	9.41 836	51	0.58 164	9.98 558	3	19
42	9.40 442	48	9.41 887	52	0.58 113	9.98 555	4	18
43	9.40 490	48	9.41 939	51	0.58 061	9.98 551	3	17
44	9.40 538	48	9.41 990	51	0.58 010	9.98 548	3	16
45	9.40 586	48	9.42 041	52	0.57 959	9.98 545	4	15
46	9.40 634	48	9.42 093	51	0.57 907	9.98 541	3	14
47	9.40 682	48	9.42 144	51	0.57 856	9.98 538	3	13
48	9.40 730	48	9.42 195	51	0.57 805	9.98 535	4	12
49	9.40 778	47	9.42 246	51	0.57 754	9.98 531	3	11
50	9.40 825	48	9.42 297	51	0.57 703	9.98 528	3	10
51	9.40 873	48	9.42 348	51	0.57 652	9.98 525	4	9
52	9.40 921	47	9.42 399	51	0.57 601	9.98 521	3	8
53	9.40 968	48	9.42 450	51	0.57 550	9.98 518	3	7
54	9.41 016	47	9.42 501	51	0.57 499	9.98 515	4	6
55	9.41 063	48	9.42 552	51	0.57 448	9.98 511	3	5
56	9.41 111	47	9.42 603	50	0.57 397	9.98 508	3	4
57	9.41 158	47	9.42 653	51	0.57 347	9.98 505	4	3
58	9.41 205	47	9.42 704	51	0.57 296	9.98 501	3	2
59	9.41 252	48	9.42 755	50	0.57 245	9.98 498	4	1
60	9.41 300		9.42 805		0.57 195	9.98 494		0
	L SIN	D	L TAN	CD	L COT	L COS	D	345°... 165°...
	L COS		L COT		L TAN	L SIN		255°... 75°...

15°... 195°...		L SIN		L TAN		L COT	L COS			PROP. PTS.
105°... 285°...		L COS	D	L COT	CD	L TAN	L SIN	D		
0	9.41 300			9.42 805	51	0.57 195	9.98 494	3	60	
1	9.41 347		47	9.42 856	50	0.57 144	9.98 491	3	59	
2	9.41 394		47	9.42 906	51	0.57 094	9.98 488	4	58	
3	9.41 441		47	9.42 957	50	0.57 043	9.98 484	3	57	
4	9.41 488		47	9.43 007	50	0.58 993	9.98 481	4	56	51 50
5	9.41 535			9.43 057	51	0.56 943	9.98 477	3	55	5.1 5.0
6	9.41 582		47	9.43 108	50	0.56 892	9.98 474	3	54	10.2 10.0
7	9.41 628		46	9.43 158	50	0.56 842	9.98 471	4	53	15.3 15.0
8	9.41 675		47	9.43 208	50	0.56 792	9.98 467	3	52	20.4 20.0
9	8.41 722		47	9.43 258	50	0.56 742	9.98 464	4	51	25.5 25.0
10	9.41 768		47	9.43 308	50	0.56 692	9.98 460	3	50	30.6 30.0
11	9.41 815		48	9.43 358	50	0.56 642	9.98 457	4	49	35.7 35.0
12	9.41 861		47	9.43 408	50	0.56 592	9.98 453	3	48	40.8 40.0
13	9.41 908		46	9.43 458	50	0.56 542	9.98 450	4	47	45.9 45.0
14	9.41 954		47	9.43 508	50	0.56 492	9.98 447	3	46	
15	9.42 001			9.43 558	49	0.56 442	9.98 443	4	45	49 48
16	9.42 047		46	9.43 607	50	0.56 393	9.98 440	3	44	4.9 4.8
17	9.42 093		46	9.43 657	50	0.56 343	9.98 436	4	43	9.8 9.6
18	9.42 140		47	9.43 707	50	0.56 293	9.98 433	3	42	14.7 14.4
19	9.42 186		46	9.43 756	49	0.56 244	8.98 429	4	41	19.6 19.2
20	9.42 232		46	9.43 806	50	0.56 194	8.98 426	3	40	24.5 24.0
21	9.42 278		46	9.43 855	49	0.56 145	9.98 422	4	39	29.4 28.8
22	9.42 324		46	9.43 905	50	0.56 095	9.98 419	3	38	34.3 33.6
23	9.42 370		46	9.43 954	49	0.56 046	9.98 415	4	37	39.2 38.4
24	9.42 416		45	9.44 004	50	0.55 996	8.98 412	3	36	44.1 43.2
25	9.42 461			9.44 053	49	0.55 947	9.98 409	4	35	
26	9.42 507		46	9.44 102	49	0.55 898	8.98 405	3	34	
27	9.42 553		46	9.44 151	50	0.55 849	9.98 402	4	33	47 46
28	9.42 599		45	9.44 201	49	0.55 799	9.98 398	3	32	4.7 4.6
29	9.42 644		46	9.44 250	49	0.55 750	9.98 395	4	31	9.4 9.2
30	9.42 690		45	9.44 299	49	0.55 701	9.98 391	3	30	14.1 13.8
31	9.42 735		46	9.44 348	49	0.55 652	9.98 388	4	29	18.8 18.4
32	9.42 781		45	9.44 397	49	0.55 603	9.98 384	3	28	23.5 23.0
33	9.42 826		46	9.44 446	49	0.55 554	9.98 381	4	27	28.2 27.6
34	9.42 872		45	9.44 495	49	0.55 505	9.98 377	3	26	32.9 32.2
35	9.42 917			9.44 544	48	0.55 456	9.98 373	4	25	37.6 36.8
36	9.42 962		45	9.44 592	49	0.55 408	9.98 370	3	24	42.3 41.4
37	9.43 008		46	9.44 641	49	0.55 359	9.98 366	4	23	
38	9.43 053		45	9.44 690	48	0.55 310	9.98 363	3	22	
39	9.43 098		45	9.44 738	49	0.55 262	9.98 359	4	21	45 44
40	9.43 143			9.44 787	49	0.55 213	9.98 356	3	20	4.5 4.4
41	9.43 188		45	9.44 836	48	0.55 164	9.98 352	4	19	9.0 8.8
42	9.43 233		45	9.44 884	49	0.55 116	9.98 349	3	18	13.5 13.2
43	9.43 278		45	9.44 933	48	0.55 067	9.98 345	4	17	18.0 17.6
44	9.43 323		44	9.44 981	48	0.55 019	9.98 342	3	16	22.5 22.0
45	9.43 367			9.45 029	49	0.54 971	9.98 338	4	15	27.0 26.4
46	9.43 412		45	9.45 078	48	0.54 922	9.98 334	3	14	31.5 30.8
47	9.43 457		45	9.45 126	48	0.54 874	9.98 331	4	13	36.0 35.2
48	9.43 502		44	9.45 174	48	0.54 826	9.98 327	3	12	40.5 39.6
49	9.43 546		45	9.45 222	49	0.54 778	9.98 324	4	11	
50	9.43 5591		44	9.45 271	48	0.54 729	9.98 320	3	10	4 3
51	9.43 635		45	9.45 319	48	0.54 681	9.98 317	4	9	0.4 0.3
52	9.43 680		44	9.45 367	48	0.54 633	9.98 313	3	8	0.8 0.6
53	9.43 724		45	9.45 415	48	0.54 585	9.98 309	4	7	1.2 0.9
54	9.43 769		44	9.45 463	48	0.54 537	9.98 306	3	6	1.6 1.2
55	9.43 813			9.45 511	48	0.54 489	9.98 302	4	5	2.0 1.5
56	9.43 857		44	9.45 559	47	0.54 441	9.98 299	3	4	2.4 1.8
57	9.43 901		44	9.45 606	48	0.54 394	9.98 295	4	3	2.8 2.1
58	9.43 946		45	9.45 654	48	0.54 346	9.98 291	3	2	3.2 2.4
59	9.43 990		44	9.45 702	48	0.54 298	9.98 288	4	1	3.6 2.7
60	9.44 034			9.45 750		0.54 250	9.98 284		0	
	L SIN		D	L TAN	CD	L COT	L COS	D		344°... 164°...
	L COS			L COT		L TAN	L SIN			254°... 74°...

17°... 197°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
107°... 287°...	L COS		L COT		L TAN	L SIN		
0	9.46 594	41	9.48 534	45	0.51 466	9.98 060	4	60
1	9.46 635	41	9.48 579	45	0.51 421	9.98 056	4	59
2	9.46 676	41	9.48 624	45	0.51 376	9.98 052	4	58
3	9.46 717	41	9.48 669	45	0.51 331	9.98 048	4	57
4	9.46 758	42	9.48 714	45	0.51 286	9.98 044	4	56
5	9.46 800	41	9.48 759	45	0.51 241	9.98 040	4	55
6	9.46 841	41	9.48 804	45	0.51 198	9.98 038	4	54
7	9.46 882	41	9.48 849	45	0.51 151	9.98 032	4	53
8	9.46 923	41	9.48 894	45	0.51 106	9.98 029	4	52
9	9.46 964	41	9.48 939	45	0.51 061	9.98 025	4	51
10	9.47 005	40	9.48 984	45	0.51 016	9.98 021	4	50
11	9.47 045	41	9.49 029	44	0.50 971	9.98 017	4	49
12	9.47 086	41	9.49 073	45	0.50 927	9.98 013	4	48
13	9.47 127	41	9.49 118	45	0.50 882	9.98 009	4	47
14	9.47 168	41	9.49 163	44	0.50 837	9.98 005	4	46
15	9.47 209	40	9.49 207	45	0.50 793	9.98 001	4	45
16	9.47 249	41	9.49 252	44	0.50 748	9.97 997	4	44
17	9.47 290	40	9.49 296	45	0.50 704	9.97 993	4	43
18	9.47 330	41	9.49 341	44	0.50 659	9.97 989	3	42
19	9.47 371	40	9.49 385	45	0.50 615	9.97 986	4	41
20	9.47 411	41	9.49 430	44	0.50 570	9.97 982	4	40
21	9.47 452	40	9.49 474	45	0.50 526	9.97 978	4	39
22	9.47 492	41	9.49 519	44	0.50 481	9.97 974	4	38
23	9.47 533	40	9.49 563	44	0.50 437	9.97 970	4	37
24	9.47 573	40	9.49 507	45	0.50 393	9.97 966	4	36
25	9.47 613	41	9.49 652	44	0.50 348	9.97 962	4	35
26	9.47 654	40	9.49 696	44	0.50 304	9.97 958	4	34
27	9.47 694	40	9.49 740	44	0.50 260	9.97 954	4	33
28	9.47 734	40	9.49 784	44	0.50 216	9.97 950	4	32
29	9.47 774	40	9.49 828	44	0.50 172	9.97 946	4	31
30	9.47 814	40	9.49 872	44	0.50 128	9.97 942	4	30
31	9.47 854	40	9.49 916	44	0.50 084	9.97 938	4	29
32	9.47 894	40	9.49 960	44	0.50 040	9.97 934	4	28
33	9.47 934	40	9.50 004	44	0.49 996	9.97 930	4	27
34	9.47 974	40	9.50 048	44	0.49 952	9.97 926	4	26
35	9.48 014	40	9.50 092	44	0.49 908	9.97 922	4	25
36	9.48 054	40	9.50 136	44	0.49 864	9.97 918	4	24
37	9.48 094	39	9.50 180	43	0.49 820	9.97 914	4	23
38	9.48 133	40	9.50 223	44	0.49 777	9.97 910	4	22
39	9.48 173	40	9.50 267	44	0.49 733	9.97 906	4	21
40	9.48 213	39	9.50 311	44	0.49 689	9.97 902	4	20
41	9.48 252	40	9.50 355	43	0.49 645	9.97 898	4	19
42	9.48 292	40	9.50 398	44	0.49 602	9.97 894	4	18
43	9.48 332	39	9.50 442	43	0.49 558	9.97 890	4	17
44	9.48 371	40	9.50 485	44	0.49 515	9.97 886	4	16
45	9.48 411	39	9.50 529	43	0.49 471	9.97 882	4	15
46	9.48 450	40	9.50 572	44	0.49 428	9.97 878	4	14
47	9.48 490	39	9.50 616	43	0.49 384	9.97 874	4	13
48	9.48 529	39	9.50 659	44	0.49 341	9.97 870	4	12
49	9.48 568	39	9.50 703	43	0.49 297	9.97 866	5	11
50	9.48 507	40	9.50 746	43	0.49 254	9.97 861	4	10
51	9.48 647	39	9.50 789	44	0.49 211	9.97 857	4	9
52	9.48 686	39	9.50 833	43	0.49 167	9.97 853	4	8
53	9.48 725	39	9.50 876	43	0.49 124	9.97 849	4	7
54	9.48 764	39	9.50 919	43	0.49 081	9.97 845	4	6
55	9.48 803	39	9.50 962	43	0.49 038	9.97 841	4	5
56	9.48 842	39	9.51 005	43	0.48 995	9.97 837	4	4
57	9.48 881	39	9.51 048	44	0.48 952	9.97 833	4	3
58	9.48 920	39	9.51 092	43	0.48 908	9.97 829	4	2
59	9.48 959	39	9.51 135	43	0.48 865	9.97 825	4	1
60	9.48 998		9.51 178		0.48 822	9.97 821		0
	L SIN	D	L TAN	CD	L COT	L COS	D	342°... 162°...
	L COS		L COT		L TAN	L SIN		252°... 72°...

18°... 198°...		L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.	
108°... 288°...		L COS		L COT		L TAN	L SIN			
0	9.48 098	39	9.51 178	43	0.48 822	9.97 821	4	60		
1	9.49 037	39	9.51 221	43	0.48 779	9.97 817	5	59		
2	9.49 076	39	9.51 264	42	0.48 736	9.97 812	4	58	43	42
3	9.49 115	38	9.51 306	43	0.48 694	9.97 808	4	57	4.3	4.2
4	9.49 153	39	9.51 349	43	0.48 651	9.97 804	4	56	8.6	8.4
5	9.49 192	39	9.51 392	43	0.48 608	9.97 800	4	55	12.9	12.6
6	9.49 231	38	9.51 435	43	0.48 565	9.97 796	4	54	17.2	16.8
7	9.49 269	39	9.51 478	42	0.48 522	9.97 792	4	53	21.5	21.0
8	9.49 308	39	9.51 520	43	0.48 480	9.97 788	4	52	25.8	25.2
9	9.49 347	38	9.51 563	43	0.48 437	9.97 784	5	51	30.1	29.4
10	9.49 385	39	9.51 606	42	0.48 394	9.97 779	4	50	34.4	33.6
11	9.49 424	38	9.51 648	43	0.48 352	9.97 775	4	49	38.7	37.8
12	9.49 462	38	9.51 691	43	0.48 309	9.97 771	4	48		
13	9.49 500	39	9.51 734	42	0.48 266	9.97 767	4	47	41	
14	9.49 539	38	9.51 776	43	0.48 224	9.97 763	4	46		
15	9.49 577	38	9.51 819	42	0.48 181	9.97 759	5	45	1	4.1
16	9.49 615	39	9.51 861	42	0.48 139	9.97 754	4	44	2	8.2
17	9.49 654	38	9.51 903	43	0.48 097	9.97 750	4	43	3	12.3
18	9.49 692	38	9.51 946	42	0.48 054	9.97 746	4	42	4	16.4
19	9.49 730	38	9.51 988	43	0.48 012	9.97 742	4	41	5	20.5
20	9.49 768	38	9.52 031	42	0.47 969	9.97 738	4	40	6	24.8
21	9.49 806	38	9.52 073	42	0.47 927	9.97 734	5	39	7	28.7
22	9.49 844	38	9.52 115	42	0.47 885	9.97 729	4	38	8	32.8
23	9.49 882	38	9.52 157	43	0.47 843	9.97 725	4	37	9	36.9
24	9.49 920	38	9.52 200	42	0.47 800	9.97 721	4	36		
25	9.49 958	38	9.52 242	42	0.47 758	9.97 717	4	35	39	38
26	9.49 996	38	9.52 284	42	0.47 716	9.97 713	5	34	1	3.9
27	9.50 034	38	9.52 326	42	0.47 674	9.97 708	4	33	2	7.8
28	9.50 072	38	9.52 368	42	0.47 632	9.97 704	4	32	3	11.7
29	9.50 110	38	9.52 410	42	0.47 590	9.97 700	4	31	4	15.6
30	9.50 148	37	9.52 452	42	0.47 548	9.97 699	4	30	5	19.5
31	9.50 185	38	9.52 494	42	0.47 506	9.97 691	5	29	6	23.4
32	9.50 223	38	9.52 536	42	0.47 464	9.97 687	4	28	7	27.3
33	9.50 261	37	9.52 578	42	0.47 422	9.97 683	4	27	8	31.2
34	9.50 298	38	9.52 620	41	0.47 380	9.97 679	5	26	9	35.1
35	9.50 336	38	9.52 661	42	0.47 339	9.97 674	4	25		
36	9.50 374	37	9.52 703	42	0.47 297	9.97 670	4	24	37	36
37	9.50 411	38	9.52 745	42	0.47 255	9.97 666	4	23		
38	9.50 449	37	9.52 787	42	0.47 213	9.97 662	5	22	1	3.7
39	9.50 486	37	9.52 829	41	0.47 171	9.97 657	4	21	2	7.4
40	9.50 523	38	9.52 870	42	0.47 130	9.97 653	4	20	3	11.1
41	9.50 561	37	9.52 912	41	0.47 088	9.97 649	4	19	4	14.8
42	9.50 598	37	9.52 953	42	0.47 047	9.97 645	5	18	5	18.5
43	9.50 635	38	9.52 995	42	0.47 005	9.97 640	4	17	6	22.2
44	9.50 673	37	9.52 037	41	0.46 963	9.97 636	4	16	7	25.9
45	9.50 710	37	9.53 078	42	0.46 922	9.97 632	4	15	8	29.6
46	9.50 747	37	9.53 120	41	0.46 880	9.97 628	5	14	9	33.3
47	9.50 784	37	9.53 161	41	0.46 839	9.97 623	4	13		
48	9.50 821	37	9.53 202	42	0.46 798	9.97 619	4	12		
49	9.50 858	38	9.53 244	41	0.46 756	9.97 615	5	11		
50	9.50 896	37	9.53 285	42	0.46 715	9.97 610	4	10	5	4
51	9.50 933	37	9.53 327	41	0.46 673	9.97 606	4	9	1	0.5
52	9.50 970	37	9.53 368	41	0.46 632	9.97 602	5	8	2	1.0
53	9.51 007	36	9.53 409	41	0.46 591	9.97 597	4	7	3	1.5
54	9.51 043	37	9.53 450	42	0.46 550	9.97 593	4	6	4	2.0
55	9.51 080	37	9.53 492	41	0.46 508	9.97 589	5	5	5	2.5
56	9.51 117	37	9.53 533	41	0.46 467	9.97 584	4	4	6	3.0
57	9.51 154	37	9.53 574	41	0.46 426	9.97 580	4	3	7	3.5
58	9.51 191	36	9.53 615	41	0.46 385	9.97 576	5	2	8	4.0
59	9.51 227	37	9.53 656	41	0.46 344	9.97 571	4	1	9	4.5
60	9.51 264		9.53 697		0.46 303	9.97 567		0		
		L SIN	D	L TAN	CD	L COT	L COS	D	341°... 161°...	
		L COS		L COT		L TAN	L SIN		251°... 71°...	

19°... 199°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
109°... 289°...	L COS		L COT		L TAN	L SIN		
0	9.51 264	37	9.53 697	41	0.46 303	9.97 567	4	60
1	9.51 301	37	9.53 738	41	0.46 262	9.97 563	5	59
2	9.51 338	36	9.53 779	41	0.46 221	9.97 558	4	58
3	9.51 374	37	9.53 820	41	0.46 180	9.97 554	4	67
4	9.51 411	38	9.53 881	41	0.48 139	9.97 550	5	58
5	9.51 447	37	9.53 902	41	0.48 098	9.97 546	4	55
6	9.51 484	36	9.53 943	41	0.48 067	9.97 541	5	54
7	9.51 520	37	9.53 984	41	0.48 016	9.97 538	4	63
8	9.51 557	36	9.54 025	40	0.45 975	9.97 532	4	52
9	9.51 593	36	9.54 065	41	0.45 935	9.97 528	5	51
10	9.51 629	37	9.54 106	41	0.45 894	9.97 523	4	50
11	9.51 666	38	9.54 147	40	0.45 853	9.97 519	4	49
12	9.51 702	36	9.54 187	41	0.45 813	9.97 515	5	48
13	9.51 738	36	9.54 228	41	0.45 772	9.97 510	4	47
14	9.51 774	37	9.54 269	40	0.45 731	9.97 506	5	46
15	9.51 811	36	9.54 309	41	0.46 691	9.97 501	4	45
16	9.51 847	36	9.54 350	40	0.45 650	9.97 497	5	44
17	9.51 883	36	9.54 390	41	0.45 610	9.97 492	4	43
18	9.51 919	36	9.54 431	40	0.45 569	9.97 488	4	42
19	8.51 955	36	9.54 471	41	0.45 529	9.97 484	5	41
20	9.51 991	38	9.54 512	40	0.45 488	9.97 479	4	40
21	9.52 027	36	9.54 552	41	0.45 448	9.97 475	5	39
22	9.52 063	36	9.54 593	40	0.45 407	9.97 470	4	38
23	9.52 099	36	9.54 633	40	0.45 367	9.97 466	5	37
24	9.52 135	36	9.54 673	41	0.45 327	9.97 461	4	36
25	9.52 171	36	9.54 714	40	0.45 286	9.97 457	4	35
26	9.52 207	35	9.54 754	40	0.45 246	9.97 453	5	34
27	9.52 242	36	9.54 794	41	0.45 206	9.97 448	4	33
28	9.52 278	36	9.54 835	40	0.45 165	9.97 444	4	32
29	9.52 314	36	9.54 875	40	0.45 125	9.97 439	5	31
30	9.52 350	35	9.54 915	40	0.45 085	9.97 435	5	30
31	9.52 385	36	9.54 955	40	0.45 045	9.97 430	4	29
32	9.52 421	35	9.54 995	40	0.45 005	9.97 426	5	28
33	9.52 456	36	9.55 035	40	0.44 965	9.97 421	4	27
34	9.52 492	35	9.55 075	40	0.44 925	9.97 417	5	26
35	9.52 527	36	9.55 115	40	0.44 885	9.97 412	4	25
36	9.52 563	35	9.55 155	40	0.44 845	9.97 408	5	24
37	9.52 598	36	9.55 195	40	0.44 805	9.97 403	4	23
38	9.52 634	35	9.55 235	40	0.44 765	9.97 399	5	22
39	9.52 669	36	9.55 275	40	0.44 725	9.97 394	4	21
40	9.52 705	35	9.55 315	40	0.44 685	9.97 390	5	20
41	9.52 740	35	9.55 355	40	0.44 645	9.97 385	4	19
42	9.52 775	36	9.55 395	49	0.44 605	9.97 381	5	18
43	9.52 811	35	9.55 434	40	0.44 566	9.97 376	4	17
44	9.52 846	35	9.55 474	40	0.44 526	9.97 372	5	16
45	9.52 881	35	9.55 514	40	0.44 486	9.97 367	4	15
46	9.52 916	35	9.55 554	39	0.44 446	9.97 363	5	14
47	9.52 961	35	9.55 593	40	0.44 407	9.97 358	5	13
48	9.52 086	35	9.55 633	40	0.44 367	9.97 363	4	12
49	9.53 021	35	9.55 673	39	0.44 327	9.97 349	5	11
50	9.53 056	36	9.55 712	40	0.44 288	9.97 344	4	10
51	9.53 092	34	9.55 752	39	0.44 248	9.97 340	5	9
52	9.53 126	35	9.55 791	40	0.44 209	9.97 335	4	8
53	9.53 161	35	9.55 831	39	0.44 169	9.97 331	5	7
54	9.53 196	35	9.55 870	40	0.44 130	9.97 326	4	6
55	9.53 231	35	9.55 910	39	0.44 090	9.97 322	5	5
56	9.53 266	35	9.55 949	40	0.44 051	9.97 317	5	4
57	9.53 301	35	9.55 989	39	0.44 011	9.97 312	4	3
58	9.53 336	34	9.56 028	39	0.43 972	9.97 308	5	2
59	9.53 370	35	9.56 067	40	0.43 933	9.97 303	4	1
60	9.53 405		9.56 107		0.43 893	9.97 299		0
	L SIN	D	L TAN	CD	L COT	L COS	D	340°... 160°...
	L COS		L COT		L TAN	L SIN		250°... 70°...

20°... 200°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
110°... 290°...	L COS		L COT		L TAN	L SIN		
0	9.53 405	35	9.56 107	39	0.43 893	9.97 299	5	60
1	9.53 440	35	9.56 146	39	0.43 854	9.97 294	5	59
2	9.53 475	34	9.56 185	39	0.43 815	9.97 289	4	58
3	9.53 509	35	9.56 224	40	0.43 776	9.97 285	5	57
4	9.53 544	34	9.56 264	49	0.43 736	9.97 280	4	56
5	9.53 578	35	9.56 303	39	0.43 697	9.97 276	5	55
6	9.53 613	34	9.56 342	39	0.43 658	9.97 271	5	54
7	9.53 647	35	9.56 381	39	0.43 619	9.97 266	4	53
8	9.53 682	34	9.56 420	39	0.43 580	9.97 262	5	52
9	9.53 716	35	9.56 459	39	0.43 541	9.97 257	5	51
10	9.53 751	34	9.56 498	39	0.43 502	9.97 252	4	50
11	9.53 785	34	9.56 537	39	0.43 463	9.97 248	5	49
12	9.53 819	35	9.56 576	39	0.43 424	9.97 243	5	48
13	9.53 854	34	9.56 615	39	0.43 385	9.97 238	4	47
14	9.53 888	34	9.56 654	39	0.43 346	9.97 234	5	46
15	9.53 922	35	9.56 693	39	0.43 307	9.97 229	5	45
16	9.53 957	34	9.56 732	39	0.43 268	9.97 224	4	44
17	9.53 991	34	9.56 771	39	0.43 229	9.97 220	5	43
18	9.54 025	34	9.56 810	39	0.43 190	9.97 215	5	42
19	9.54 059	34	9.56 849	38	0.43 151	9.97 210	4	41
20	9.54 093	34	9.56 887	39	0.43 113	9.97 206	5	40
21	9.54 127	34	9.56 926	39	0.43 074	9.97 201	5	39
22	9.54 161	34	9.56 965	39	0.43 035	9.97 196	4	38
23	9.54 195	34	9.57 004	38	0.42 996	9.97 192	5	37
24	9.54 229	34	9.57 042	39	0.42 958	9.97 187	5	36
25	9.54 263	34	9.57 081	39	0.42 919	9.97 182	4	35
26	9.54 297	34	9.57 120	38	0.42 880	9.97 178	5	34
27	9.54 331	34	9.57 158	39	0.42 842	9.97 173	5	33
28	9.54 365	34	9.57 197	38	0.42 803	9.97 168	5	32
29	9.54 399	34	9.57 235	39	0.42 765	9.97 163	4	31
30	9.54 433	33	9.57 274	38	0.42 726	9.97 159	5	30
31	9.54 466	34	9.57 312	39	0.42 688	9.97 154	5	29
32	9.54 500	34	9.57 351	38	0.42 649	9.97 149	4	28
33	9.54 534	33	9.57 389	39	0.42 611	9.97 145	5	27
34	9.54 567	34	9.57 428	38	0.42 572	9.97 140	5	26
35	9.54 601	34	9.57 466	38	0.42 534	9.97 135	5	25
36	9.54 635	33	9.57 504	39	0.42 496	9.97 130	4	24
37	9.54 668	34	9.57 543	38	0.42 457	9.97 126	5	23
38	9.54 702	33	9.57 581	38	0.42 419	9.97 121	5	22
39	9.54 735	34	9.57 619	39	0.42 381	9.97 116	5	21
40	9.54 769	33	9.57 658	38	0.42 342	9.97 111	4	20
41	9.54 802	34	9.57 696	38	0.42 304	9.97 107	5	19
42	9.54 836	33	9.57 734	38	0.42 266	9.97 102	5	18
43	9.54 869	34	9.57 772	38	0.42 228	9.97 097	5	17
44	9.54 903	33	9.57 810	39	0.42 190	9.97 092	5	16
45	9.54 936	33	9.57 849	38	0.42 151	9.97 087	4	15
46	9.54 969	34	9.57 887	38	0.42 113	9.97 083	5	14
47	9.55 003	33	9.57 925	38	0.42 075	9.97 078	5	13
48	9.55 036	33	9.57 963	38	0.42 037	9.97 073	5	12
49	9.55 069	33	9.58 001	38	0.41 999	9.97 068	5	11
50	9.55 102	34	9.58 039	38	0.41 961	9.97 063	4	10
51	9.55 136	33	9.58 077	38	0.41 923	9.97 059	5	9
52	9.55 169	33	9.58 115	38	0.41 885	9.97 054	5	8
53	9.55 202	33	9.58 153	38	0.41 847	9.97 049	5	7
54	9.55 235	33	9.58 191	38	0.41 809	9.97 044	5	6
55	9.55 268	33	9.58 229	38	0.41 771	9.97 039	4	5
56	9.55 301	33	9.58 267	37	0.41 733	9.97 035	5	4
57	9.55 334	33	9.58 304	38	0.41 696	9.97 030	5	3
58	9.55 367	33	9.58 342	38	0.41 658	9.97 025	5	2
59	9.55 400	33	9.58 380	38	0.41 620	9.97 020	5	1
60	9.55 433		9.58 418		0.41 582	9.97 015		0
								339°... 159°...
								249°... 69°...

21°... 201°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP PTS.
111°... 291°...	L COS		L COT		L TAN	L SIN		
0	9.55 433	33	9.58 418	37	0.41 582	9.97 016	5	60
1	9.55 466	33	9.58 455	38	0.41 546	9.97 010	5	59
2	9.55 499	33	9.58 493	38	0.41 507	9.97 005	5	58
3	9.55 532	32	9.58 531	38	0.41 469	9.97 001	5	57
4	9.55 564	33	9.58 569	37	0.41 431	9.97 998	5	56
5	9.55 597	33	9.58 608	38	0.41 394	9.88 991	5	55
6	9.55 630	33	9.58 644	37	0.41 358	9.88 988	5	54
7	9.55 663	32	9.58 681	38	0.41 319	9.96 981	5	53
8	9.55 695	33	9.58 719	38	0.41 281	9.96 978	5	52
9	9.55 728	33	9.58 757	37	0.41 243	9.96 971	5	51
10	9.55 761	32	9.58 794	38	0.41 208	9.96 966	4	50
11	9.55 793	33	9.58 832	37	0.41 188	9.98 982	5	49
12	9.55 826	32	9.58 869	38	0.41 131	9.96 957	5	48
13	9.55 858	33	9.58 907	37	0.41 093	9.96 952	5	47
14	9.55 891	32	9.58 944	37	0.41 056	9.96 947	5	46
15	9.55 923	33	9.58 981	38	0.41 019	9.96 942	5	45
16	9.55 956	32	9.59 019	37	0.40 981	9.96 937	5	44
17	9.55 988	33	9.59 056	38	0.40 944	9.96 932	5	43
18	9.56 021	32	9.59 094	37	0.40 906	9.96 927	5	42
19	9.56 053	32	9.59 131	37	0.40 869	9.96 922	6	41
20	9.56 085	33	9.59 168	37	0.40 832	9.96 917	5	40
21	9.56 118	32	9.59 205	38	0.40 795	9.96 912	6	39
22	9.56 150	32	9.59 243	37	0.40 757	9.96 907	4	38
23	9.56 182	33	9.59 280	37	0.40 720	9.96 903	5	37
24	9.56 215	32	9.59 317	37	0.40 683	9.96 898	5	36
25	9.56 247	32	9.59 354	37	0.40 648	9.96 893	5	35
26	9.56 279	32	9.59 391	38	0.40 609	9.98 888	5	34
27	9.56 311	32	9.59 429	37	0.40 571	9.96 883	5	33
28	9.56 343	32	9.59 466	37	0.40 534	9.96 878	5	32
29	9.56 375	33	9.59 503	37	0.40 497	9.96 873	5	31
30	9.56 408	32	9.59 540	37	0.40 460	9.96 868	6	30
31	9.56 440	32	9.59 577	37	0.40 423	9.96 863	6	29
32	9.56 472	32	9.59 614	37	0.40 388	9.96 858	5	28
33	9.56 504	32	9.59 651	37	0.40 349	9.96 853	5	27
34	9.56 538	32	9.59 688	37	0.40 312	9.96 848	6	26
35	9.56 568	31	9.59 725	37	0.40 275	9.96 843	5	25
36	9.56 599	32	9.59 762	37	0.40 238	9.96 838	5	24
37	9.56 631	32	9.59 799	36	0.40 201	9.96 833	5	23
38	9.56 663	32	9.59 835	37	0.40 165	9.96 828	5	22
39	9.56 695	32	9.59 872	37	0.40 128	9.96 823	5	21
40	9.56 727	32	9.59 909	37	0.40 091	9.96 818	5	20
41	9.56 759	31	9.59 946	37	0.40 054	9.96 813	5	19
42	9.56 790	32	9.59 983	36	0.40 017	9.96 808	5	18
43	9.56 822	32	9.60 019	37	0.39 981	9.96 803	5	17
44	9.56 854	32	9.60 056	37	0.39 944	9.96 798	5	16
45	9.56 886	31	9.60 093	37	0.39 907	9.96 793	5	15
46	9.56 917	32	9.60 130	36	0.39 870	9.96 788	5	14
47	9.56 949	31	9.60 166	37	0.39 834	9.96 783	5	13
48	9.56 980	32	9.60 203	37	0.39 797	9.96 778	5	12
49	9.56 012	32	9.60 240	36	0.39 760	9.96 772	5	11
50	9.57 044	31	9.60 276	37	0.39 724	9.96 767	5	10
51	9.57 075	32	9.60 313	36	0.39 687	9.98 762	5	9
52	9.57 107	31	9.60 349	37	0.39 651	9.96 757	5	8
53	9.57 133	31	9.60 386	36	0.39 614	9.96 752	5	7
54	9.57 169	32	9.60 422	37	0.39 578	9.96 747	5	6
55	9.57 201	31	9.60 459	36	0.39 541	9.96 742	5	5
56	9.57 232	32	9.60 495	37	0.39 505	9.96 737	5	4
57	9.57 264	31	9.60 532	36	0.39 468	9.96 732	6	3
58	9.57 295	31	9.60 568	37	0.39 432	9.98 727	5	2
59	9.57 326	32	9.60 605	36	0.39 395	9.96 722	5	1
60	9.57 358		9.60 641		0.39 359	9.96 717		0
	L SIN	D	L TAN	CD	L COT	L COS	D	338°... 158°...
	L COS		L COT		L TAN	L SIN		248°... 68°...

22°... 202°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP PTS.
112°... 292°	L COS		L COT		L TAN	L SIN		
0	9.57 358	31	9.60 641	36	0.39 359	9.96 717	60	
1	9.57 389	31	9.60 677	37	0.39 323	9.96 711	59	37 36
2	9.57 420	31	9.60 714	36	0.39 286	9.96 706	58	
3	9.57 451	31	9.60 750	36	0.39 250	9.96 701	57	1 3.7 3.6
4	9.57 482	32	9.60 786	37	0.39 214	9.96 696	56	2 7.4 7.2
							5	3 11.1 10.8
5	9.57 514	31	9.60 823	36	0.39 177	9.96 691	55	4 14.8 14.4
6	9.57 545	31	9.60 859	36	0.39 141	9.96 686	54	5 18.5 18.0
7	9.57 576	31	9.60 895	36	0.39 105	9.96 681	53	6 22.2 21.6
8	9.57 607	31	9.60 931	36	0.39 069	9.96 676	52	7 25.9 25.2
9	9.57 638	31	9.60 967	37	0.39 033	9.96 670	51	8 29.6 28.8
							5	9 33.3 32.4
10	9.57 669	31	9.61 004	36	0.38 996	9.96 665	50	
11	9.57 700	31	9.61 040	36	0.38 960	9.96 660	49	
12	9.57 731	31	9.61 076	36	0.38 924	9.96 655	48	
13	9.57 762	31	9.61 112	36	0.38 888	9.96 650	47	35
14	9.57 793	31	9.61 148	36	0.38 852	9.96 645	46	
							5	1 3.5
15	9.57 824	31	9.61 184	36	0.38 816	9.96 640	45	2 7.0
16	9.57 855	30	9.61 220	36	0.38 780	9.96 634	44	3 10.5
17	9.57 885	31	9.61 256	36	0.38 744	9.96 629	43	4 14.0
18	9.57 916	31	9.61 292	36	0.38 708	9.96 624	42	5 17.5
19	9.57 947	31	9.61 328	36	0.38 672	9.96 619	41	6 21.0
							5	7 24.5
20	9.57 978	30	9.61 364	36	0.38 636	9.96 614	40	8 28.0
21	9.58 008	31	9.61 400	36	0.38 600	9.96 608	39	9 31.5
22	9.58 039	31	9.61 436	36	0.38 564	9.96 603	38	
23	9.58 070	31	9.61 472	36	0.38 528	9.96 598	37	
24	9.58 101	30	9.61 508	36	0.38 492	9.96 593	36	
							5	
25	9.58 131	31	9.61 544	35	0.38 456	9.96 588	35	32 31
26	9.58 162	30	9.61 579	36	0.38 421	9.96 582	34	
27	9.58 192	31	9.61 615	36	0.38 385	9.96 577	33	1 3.2 3.1
28	9.58 223	30	9.61 651	36	0.38 349	9.96 572	32	2 6.4 6.2
29	9.58 253	31	9.61 687	35	0.38 313	9.96 567	31	3 9.6 9.3
							5	4 12.8 12.4
30	9.58 284	30	9.61 722	36	0.38 278	9.96 562	30	5 16.0 15.5
31	9.58 314	31	9.61 758	36	0.38 242	9.96 556	29	6 19.2 18.6
32	9.58 345	30	9.61 794	36	0.38 206	9.96 551	28	7 22.4 21.7
33	9.58 375	31	9.61 830	35	0.38 170	9.96 546	27	8 25.6 24.8
34	9.58 406	30	9.61 865	36	0.38 135	9.96 541	26	9 28.8 27.9
							6	
35	9.58 346	31	9.61 901	35	0.38 099	9.96 535	25	
36	9.58 467	30	9.61 936	36	0.38 064	9.96 530	24	
37	9.58 497	30	9.61 972	36	0.38 028	9.96 525	23	30 29
38	9.58 527	30	9.62 008	35	0.37 992	9.96 520	22	1 3.0 2.9
39	9.58 557	31	9.62 043	36	0.37 957	9.96 514	21	2 6.0 5.8
							5	3 9.0 8.7
40	9.58 588	30	9.62 079	35	0.37 921	9.96 509	20	4 12.0 11.6
41	9.58 618	30	9.62 114	36	0.37 886	9.96 504	19	5 15.0 14.5
42	9.58 648	30	9.62 150	35	0.37 850	9.96 498	18	6 18.0 17.4
43	9.58 678	31	9.62 185	36	0.37 815	9.96 493	17	7 21.0 20.3
44	9.58 709	30	9.62 221	35	0.37 779	9.96 488	16	8 24.0 23.2
							5	9 27.0 26.1
45	9.58 739	30	9.62 256	36	0.37 744	9.96 483	15	
46	9.58 769	30	9.62 292	35	0.37 708	9.96 477	14	
47	9.58 799	30	9.62 327	35	0.37 673	9.96 472	13	
48	9.58 829	30	9.62 362	36	0.37 638	9.96 467	12	
49	9.58 859	30	9.62 398	35	0.37 602	9.96 461	11	6 5
							5	1 0.6 0.5
50	9.58 889	30	9.62 433	35	0.37 567	9.96 456	10	2 1.2 1.0
51	9.58 919	30	9.62 468	36	0.37 532	9.96 451	9	3 11.8 1.5
52	9.58 949	30	9.62 504	35	0.37 496	9.96 445	8	4 2.4 2.0
53	9.58 979	30	9.62 539	35	0.37 461	9.96 440	7	5 3.0 2.5
54	9.59 009	30	9.62 574	35	0.37 426	9.96 435	6	6 3.6 3.0
							5	7 4.2 3.5
55	9.59 039	30	9.62 609	36	0.37 391	9.96 429	5	8 4.8 4.0
56	9.59 069	29	9.62 645	35	0.37 355	9.96 424	4	9 5.4 4.5
57	9.59 098	30	9.62 680	35	0.37 320	9.96 419	3	
58	9.59 128	30	9.62 715	35	0.37 285	9.96 413	2	
59	9.59 158	30	9.62 750	35	0.37 250	9.96 408	1	
							5	
60	9.59 188		9.62 785		0.37 215	9.96 403	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	337°... 157°
	L COS		L COT		L TAN	L SIN		247°... 67°

23°... 203°..	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
113°... 293°..	L COS		L COT		L TAN	L SIN		
0	9.59 188	30	9.62 785	35	0.37 215	9.96 403	60	
1	9.59 218	29	9.62 820	35	0.37 180	9.96 397	59	
2	9.59 247	30	9.62 855	35	0.37 145	9.96 392	58	36 35
3	9.59 277	30	9.62 890	36	0.37 110	9.96 387	57	1 3.6 3.5
4	9.59 307	29	9.62 926	35	0.37 074	9.96 381	56	2 7.2 7.0
5	9.59 336	30	9.62 961	35	0.37 039	9.96 376	55	3 10.8 10.5
6	9.59 366	30	9.62 996	35	0.37 004	9.96 370	54	4 14.4 14.0
7	9.59 396	29	9.63 031	35	0.36 969	9.96 365	53	5 18.0 17.5
8	9.59 425	30	9.63 066	35	0.36 934	9.96 360	52	6 21.6 21.0
9	9.59 455	29	9.63 101	34	0.36 899	9.96 354	51	7 25.2 24.5
10	9.59 484	30	9.63 135	35	0.36 865	9.96 349	50	8 28.8 28.0
11	9.59 514	29	9.63 170	35	0.36 830	9.96 343	49	9 32.4 31.5
12	9.59 543	30	9.63 205	35	0.36 795	9.96 338	48	
13	9.59 573	29	9.63 240	35	0.36 760	9.96 333	47	
14	9.59 602	30	9.63 275	35	0.36 725	9.96 327	46	34
15	9.59 632	29	9.63 310	35	0.36 690	9.96 322	45	1 3.4
16	9.59 661	29	9.63 345	34	0.36 655	9.96 316	44	2 6.8
17	9.59 690	30	9.63 379	35	0.36 621	9.96 311	43	3 10.2
18	9.59 720	29	9.63 414	35	0.36 586	9.96 305	42	4 13.6
19	9.59 749	29	9.63 449	35	0.36 551	9.96 300	41	5 17.0
20	9.59 778	30	9.63 484	35	0.36 516	9.96 294	40	6 20.4
21	9.59 808	29	9.63 519	34	0.36 481	9.96 289	39	7 23.8
22	9.59 837	29	9.63 553	35	0.36 447	9.96 284	38	8 27.2
23	9.59 866	29	9.63 588	35	0.36 412	9.96 278	37	9 30.6
24	9.59 895	29	9.63 623	34	0.36 377	9.96 273	36	
25	9.59 924	30	9.63 657	35	0.36 343	9.96 267	35	
26	9.59 954	29	9.63 692	34	0.36 308	9.96 262	34	30 29
27	9.59 983	29	9.63 726	35	0.36 274	9.96 256	33	1 3.0 2.9
28	9.60 012	29	9.63 761	35	0.36 239	9.96 251	32	2 6.0 5.8
29	9.60 041	29	9.63 796	34	0.36 204	9.96 245	31	3 9.0 8.7
30	9.60 070	29	9.63 830	35	0.36 170	9.96 240	30	4 12.0 11.6
31	9.60 099	29	9.63 865	34	0.36 135	9.96 234	29	5 15.0 14.5
32	9.60 128	29	9.63 899	35	0.36 101	9.96 229	28	6 18.0 17.4
33	9.60 157	29	9.63 934	34	0.36 066	9.96 223	27	7 21.0 20.3
34	9.60 186	29	9.63 968	35	0.36 032	9.96 218	26	8 24.0 23.2
35	9.60 215	29	9.64 003	34	0.35 997	9.96 212	25	9 27.0 26.1
36	9.60 244	29	9.64 037	35	0.35 963	9.96 207	24	
37	9.60 273	29	9.64 072	34	0.35 928	9.96 201	23	28
38	9.60 302	29	9.64 106	34	0.35 894	9.96 196	22	1 2.8
39	9.60 331	28	9.64 140	35	0.35 860	9.96 190	21	2 5.6
40	9.60 359	29	9.64 175	34	0.35 825	9.96 185	20	3 8.4
41	9.60 388	29	9.64 209	34	0.35 791	9.96 179	19	4 11.2
42	9.60 417	29	9.64 243	35	0.35 757	9.96 174	18	5 14.0
43	9.60 446	28	9.64 278	34	0.35 722	9.96 168	17	6 16.8
44	9.60 474	29	9.64 312	34	0.35 688	9.96 162	16	7 19.6
45	9.60 503	29	9.64 346	35	0.35 654	9.96 157	15	8 22.4
46	9.60 532	29	9.64 381	34	0.35 619	9.96 151	14	9 25.2
47	9.60 561	29	9.64 415	34	0.35 585	9.96 146	13	
48	9.60 589	28	9.64 449	34	0.35 551	9.96 140	12	
49	9.60 618	28	9.64 483	34	0.35 517	9.96 135	11	
50	9.60 646	29	9.64 517	35	0.35 483	9.96 129	10	6 5
51	9.60 675	29	9.64 552	34	0.35 448	9.96 123	9	1 0.6 0.5
52	9.60 704	28	9.64 586	34	0.35 414	9.96 118	8	2 1.2 1.0
53	9.60 732	29	9.64 620	34	0.35 380	9.96 112	7	3 1.8 1.5
54	9.60 761	28	9.64 654	34	0.35 346	9.96 107	6	4 2.4 2.0
55	9.60 789	29	9.64 688	34	0.35 312	9.96 101	5	5 3.0 2.5
56	9.60 818	28	9.64 722	34	0.35 278	9.96 095	4	6 3.6 3.0
57	9.60 846	29	9.64 756	34	0.35 244	9.96 090	3	7 4.2 3.5
58	9.60 875	28	9.64 790	34	0.35 210	9.96 084	2	8 4.8 4.0
59	9.60 903	28	9.64 824	34	0.35 176	9.96 079	1	9 5.4 4.5
60	9.60 931		9.64 858		0.35 142	9.96 073	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	336°... 156°..
	L COS		L COT		L TAN	L SIN		246°... 66°..

24°... 204°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP PTS.
114°... 294°...	L COS		L COT		L TAN	L SIN		
0	9.60 931	29	9.64 858	34	0.35 142	9.96 073	60	
1	9.60 960	28	9.64 892	34	0.35 108	9.96 067	59	
2	9.60 988	28	9.64 926	34	0.35 074	9.96 062	58	
3	9.61 016	29	9.64 960	34	0.35 040	9.96 056	57	
4	9.61 045	28	9.64 994	34	0.35 006	9.96 050	56	34 33
5	9.61 073	28	9.65 028	34	0.34 972	9.96 045	55	1 3.4 3.3
6	9.61 101	28	9.65 062	34	0.34 938	9.96 039	54	2 6.8 6.6
7	9.61 129	29	9.65 096	34	0.34 904	9.96 034	53	3 10.2 9.9
8	9.61 158	28	9.65 130	34	0.34 870	9.96 028	52	4 13.6 13.2
9	9.61 186	28	9.65 164	33	0.34 836	9.96 022	51	5 17.0 16.5
10	9.61 214	28	9.65 197	34	0.34 803	9.96 017	50	6 20.4 19.8
11	9.61 242	28	9.65 231	34	0.34 769	9.96 011	49	7 23.8 23.1
12	9.61 270	28	9.65 265	34	0.34 735	9.96 005	48	8 27.2 26.4
13	9.61 298	28	9.65 299	34	0.34 701	9.96 000	47	9 30.6 29.7
14	9.61 326	28	9.65 333	33	0.34 667	9.95 994	46	
15	9.61 354	28	9.65 366	34	0.34 634	9.95 988	45	29
16	9.61 382	29	9.65 400	34	0.34 600	9.95 982	44	1 2.9
17	9.61 411	27	9.65 434	33	0.34 566	9.95 977	43	2 5.8
18	9.61 438	28	9.65 467	34	0.34 533	9.95 971	42	3 8.7
19	9.61 466	28	9.65 501	34	0.34 499	9.95 965	41	4 11.6
20	9.61 494	28	9.65 535	33	0.34 465	9.95 960	40	5 14.5
21	9.61 522	28	9.65 568	34	0.34 432	9.95 954	39	6 17.4
22	9.61 550	28	9.65 602	34	0.34 398	9.95 948	38	7 20.3
23	9.61 578	28	9.65 636	33	0.34 364	9.95 942	37	8 23.2
24	9.61 606	28	9.65 669	34	0.34 331	9.95 937	36	9 26.1
25	9.61 634	28	9.65 703	33	0.34 297	9.95 931	35	
26	9.61 662	27	9.65 736	34	0.34 264	9.95 925	34	28
27	9.61 689	28	9.65 770	33	0.34 230	9.95 920	33	
28	9.61 717	28	9.65 803	34	0.34 197	9.95 914	32	1 2.8
29	9.61 745	28	9.65 837	33	0.34 163	9.95 908	31	2 5.6
30	9.61 773	27	9.65 870	34	0.34 130	9.95 902	30	3 8.4
31	9.61 800	28	9.65 904	33	0.34 096	9.95 897	29	4 11.2
32	9.61 828	28	9.65 937	34	0.34 063	9.95 891	28	5 14.0
33	9.61 856	27	9.65 971	33	0.34 029	9.95 885	27	6 16.8
34	9.61 883	28	9.66 004	34	0.33 996	9.95 879	26	7 19.6
35	9.61 911	28	9.66 038	33	0.33 962	9.95 873	25	8 22.4
36	9.61 939	27	9.66 071	33	0.33 929	9.95 868	24	9 25.2
37	9.61 966	28	9.66 104	34	0.33 896	9.95 862	23	
38	9.61 994	27	9.66 138	33	0.33 862	9.95 856	22	
39	9.62 021	28	9.66 171	33	0.33 829	9.95 850	21	27
40	9.62 049	27	9.66 204	34	0.33 796	9.95 844	20	1 2.7
41	9.62 076	28	9.66 238	33	0.33 762	9.95 839	19	2 5.4
42	9.62 104	27	9.66 271	33	0.33 729	9.95 833	18	3 8.1
43	9.62 131	28	9.66 304	33	0.33 696	9.95 827	17	4 10.8
44	9.62 159	27	9.66 337	34	0.33 663	9.95 821	16	5 13.5
45	9.62 186	28	9.66 371	33	0.33 629	9.95 815	15	6 16.2
46	9.62 214	27	9.66 404	33	0.33 596	9.95 810	14	7 18.9
47	9.62 241	27	9.66 437	33	0.33 563	9.95 804	13	8 21.6
48	9.62 268	28	9.66 470	33	0.33 530	9.95 798	12	9 24.3
49	9.62 296	27	9.66 503	34	0.33 497	9.95 792	11	
50	9.62 323	27	9.66 527	33	0.33 463	9.95 786	10	6 5
51	9.62 350	27	9.66 570	33	0.33 430	9.95 780	9	1 0.6 0.5
52	9.62 377	28	9.66 603	33	0.33 397	9.95 775	8	2 1.2 1.0
53	9.62 405	27	9.66 636	33	0.33 364	9.95 769	7	3 1.8 1.5
54	9.62 432	27	9.66 669	33	0.33 331	9.95 763	6	4 2.4 2.0
55	9.62 459	27	9.66 702	33	0.33 298	9.95 757	5	5 3.0 2.5
56	9.62 486	27	9.66 735	33	0.33 265	9.95 751	4	6 3.6 3.0
57	9.62 513	28	9.66 768	33	0.33 232	9.95 745	3	7 4.2 3.5
58	9.62 541	27	9.66 801	33	0.33 199	9.95 739	2	8 4.8 4.0
59	9.62 568	27	9.66 834	33	0.33 166	9.95 733	1	9 5.4 4.5
60	9.62 595		9.66 867		0.33 133	9.95 728	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	335°... 155°...
	L COS		L COT		L TAN	L SIN		245°... 65°...

25°... 205°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
115°... 295°...	L COS		L COT		L TAN	L SIN		
0	9.62 595	27	9.68 867	33	0.33 133	9.95 728	60	
1	9.62 622	27	9.66 900	33	0.33 100	9.95 722	59	
2	9.62 649	27	9.66 933	33	0.33 087	9.95 716	58	
3	9.62 676	27	9.68 966	33	0.33 034	9.95 710	57	
4	9.62 703	27	9.66 999	33	0.33 001	9.95 704	56	
5	9.62 730	27	9.67 032	33	0.32 968	9.95 698	55	1 3.3 3.2
6	9.62 757	27	9.67 065	33	0.32 935	9.95 692	54	2 6.6 6.4
7	9.62 784	27	9.67 098	33	0.32 902	9.95 686	53	3 9.9 9.6
8	9.62 811	27	9.67 131	32	0.32 869	9.95 680	52	4 13.2 12.8
9	9.62 838	27	9.67 163	33	0.32 837	9.95 674	51	5 16.5 18.0
10	9.62 865	27	9.67 196	33	0.32 804	9.95 668	50	6 19.8 19.2
11	9.62 892	26	9.67 229	33	0.32 771	9.95 663	49	7 23.1 22.4
12	9.62 918	27	9.67 262	33	0.32 738	9.95 657	48	8 26.4 25.6
13	9.62 945	27	9.67 295	32	0.32 705	9.95 651	47	9 29.7 28.8
14	9.62 972	27	9.67 327	33	0.32 673	9.95 645	46	
15	9.62 999	27	9.67 360	33	0.32 640	9.95 639	45	27
16	9.63 026	26	9.67 393	33	0.32 607	9.95 633	44	1 2.7
17	9.63 052	27	9.67 426	32	0.32 574	9.95 627	43	2 5.4
18	9.63 079	27	9.67 458	33	0.32 542	9.95 621	42	3 8.1
19	9.63 106	27	9.67 491	33	0.32 509	9.95 615	41	4 10.8
20	9.63 133	26	9.67 524	32	0.32 476	9.95 609	40	5 13.5
21	9.63 159	27	9.67 556	33	0.32 444	9.95 603	39	6 16.2
22	9.63 186	27	9.67 589	33	0.32 411	9.95 597	38	7 18.9
23	9.63 213	28	9.67 622	32	0.32 378	9.95 591	37	8 21.6
24	9.63 239	27	9.67 654	33	0.32 346	9.95 585	36	9 24.3
25	9.63 266	26	9.67 687	32	0.32 313	9.95 579	35	
26	9.63 292	27	9.67 719	33	0.32 281	9.95 573	34	28
27	9.63 319	26	9.67 752	33	0.32 248	9.95 567	33	1 2.6
28	9.63 345	27	9.67 785	32	0.32 215	9.95 561	32	2 5.2
29	9.63 372	26	9.67 817	33	0.32 183	9.95 555	31	3 7.8
30	9.63 398	27	9.67 850	32	0.32 150	9.95 549	30	4 10.4
31	9.63 425	26	9.67 882	33	0.32 118	9.95 543	29	5 13.0
32	9.63 451	27	9.67 915	32	0.32 085	9.95 537	28	6 15.6
33	9.63 478	26	9.67 947	33	0.32 053	9.95 531	27	7 18.2
34	9.63 504	27	9.67 980	32	0.32 020	9.95 525	26	8 20.8
35	9.63 531	26	9.68 012	32	0.31 988	9.95 519	25	9 23.4
36	9.63 557	26	9.68 044	33	0.31 956	9.95 513	24	
37	9.63 583	27	9.68 077	32	0.31 923	9.95 507	23	
38	9.63 610	26	9.68 109	33	0.31 891	9.95 500	22	7
39	9.63 636	26	9.68 142	32	0.31 858	9.95 494	21	1 0.7
40	9.63 662	27	9.68 174	32	0.31 826	9.95 488	20	2 1.4
41	9.63 689	26	9.68 206	33	0.31 794	9.95 482	19	3 2.1
42	9.63 715	26	9.68 239	32	0.31 761	9.95 476	18	4 2.8
43	9.63 741	26	9.68 271	32	0.31 729	9.95 470	17	5 3.5
44	9.63 767	27	9.68 303	33	0.31 697	9.95 464	16	6 4.2
45	9.63 794	26	9.68 336	32	0.31 664	9.95 458	15	7 4.9
46	9.63 820	26	9.68 368	32	0.31 632	9.95 452	14	8 5.6
47	9.63 846	26	9.68 400	32	0.31 600	9.95 446	13	9 6.3
48	9.63 872	26	9.68 432	33	0.31 568	9.95 440	12	
49	9.63 898	26	9.68 465	32	0.31 535	9.95 434	11	
50	9.63 924	26	9.68 497	32	0.31 503	9.95 427	10	6 5
51	9.63 950	26	9.68 529	32	0.31 471	9.95 421	9	1 0.6 0.5
52	9.63 976	26	9.68 561	32	0.31 439	9.95 415	8	2 1.2 1.0
53	9.64 002	26	9.68 593	33	0.31 407	9.95 409	7	3 1.8 1.5
54	9.64 028	26	9.68 626	32	0.31 374	9.95 403	6	4 2.4 2.0
55	9.64 054	26	9.68 658	32	0.31 342	9.95 397	5	5 3.0 2.5
56	9.64 080	26	9.68 690	32	0.31 310	9.95 391	4	6 3.6 3.0
57	9.64 106	26	9.68 722	32	0.31 278	9.95 384	3	7 4.2 3.5
58	9.64 132	26	9.68 754	32	0.31 246	9.95 378	2	8 4.8 4.0
59	9.64 158	26	9.68 786	32	0.31 214	9.95 372	1	9 5.4 4.5
60	9.64 184		9.68 818		0.31 182	9.95 366	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	334°... 154°...
	L COS		L COT		L TAN	L SIN		244°... 64°

26°... 206°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
116°... 296°	L COS		L COT		L TAN	L SIN		
0	9.64 184	26	9.68 818	32	0.31 182	9.95 366	60	
1	9.64 210	26	9.68 850	32	0.31 150	9.95 360	59	
2	9.64 236	26	9.68 882	32	0.31 118	9.95 354	58	32 31
3	9.64 262	26	9.68 914	32	0.31 086	9.95 348	57	
4	9.64 288	25	9.68 946	32	0.31 054	9.95 341	56	1 3.2 3.1
5	9.64 313	26	9.68 978	32	0.31 022	9.95 335	55	2 6.4 6.2
6	9.64 339	26	9.69 010	32	0.30 990	9.95 329	54	3 9.6 9.3
7	9.64 365	26	9.69 042	32	0.30 958	9.95 323	53	4 12.8 12.4
8	9.64 391	26	9.69 074	32	0.30 926	9.95 317	52	5 16.0 15.5
9	9.64 417	25	9.69 106	32	0.30 894	9.95 310	51	6 19.2 18.6
10	9.64 442	26	9.69 138	32	0.30 862	9.95 304	50	7 22.4 21.7
11	9.64 468	26	9.69 170	32	0.30 830	9.95 298	49	8 25.6 24.8
12	9.64 494	25	9.69 202	32	0.30 798	9.95 292	48	9 28.8 27.9
13	9.64 519	26	9.69 234	32	0.30 766	9.95 286	47	
14	9.64 545	26	9.69 266	32	0.30 734	9.95 279	46	26
15	9.64 571	25	9.69 298	31	0.30 702	9.95 273	45	1 2.6
16	9.64 596	26	9.69 329	32	0.30 671	9.95 267	44	2 5.2
17	9.64 622	25	9.69 361	32	0.30 639	9.95 261	43	3 7.8
18	9.64 647	26	9.69 393	32	0.30 607	9.95 254	42	4 10.4
19	9.64 673	25	9.69 425	32	0.30 575	9.95 248	41	5 13.0
20	9.64 698	26	9.69 457	31	0.30 543	9.95 242	40	6 15.6
21	9.64 724	25	9.69 488	32	0.30 512	9.95 236	39	7 18.2
22	9.64 749	26	9.69 520	32	0.30 480	9.95 229	38	8 20.8
23	9.64 775	25	9.69 552	32	0.30 448	9.95 223	37	9 23.4
24	9.64 800	26	9.69 584	31	0.30 416	9.95 217	36	
25	9.64 826	25	9.69 615	32	0.30 385	9.95 211	35	25
26	9.64 851	26	9.69 647	32	0.30 353	9.95 204	34	1 2.5
27	9.64 877	25	9.69 679	31	0.30 321	9.95 198	33	2 5.0
28	9.64 902	26	9.69 710	32	0.30 290	9.95 192	32	3 7.5
29	9.64 927	25	9.69 742	32	0.30 258	9.95 185	31	4 10.0
30	9.64 953	25	9.69 774	31	0.30 226	9.95 179	30	5 12.5
31	9.64 978	25	9.69 805	32	0.30 195	9.95 173	29	6 15.0
32	9.65 003	26	9.69 837	32	0.30 163	9.95 167	28	7 17.5
33	9.65 029	25	9.69 868	31	0.30 132	9.95 160	27	8 20.0
34	9.65 054	25	9.69 900	32	0.30 100	9.95 154	26	9 22.5
35	9.65 079	25	9.69 932	31	0.30 068	9.95 148	25	
36	9.65 104	26	9.69 963	32	0.30 037	9.95 141	24	
37	9.65 130	25	9.69 995	31	0.30 005	9.95 135	23	24
38	9.65 155	25	9.70 026	32	0.29 974	9.95 129	22	
39	9.65 180	25	9.70 058	31	0.29 942	9.95 122	21	1 2.4
40	9.65 205	25	9.70 089	32	0.29 911	9.95 116	20	2 4.8
41	9.65 230	25	9.70 121	31	0.29 879	9.95 110	19	3 7.2
42	9.65 255	26	9.70 152	32	0.29 848	9.95 103	18	4 9.6
43	9.65 281	25	9.70 184	31	0.29 816	9.95 097	17	5 12.0
44	9.65 306	25	9.70 215	32	0.29 785	9.95 090	16	6 14.4
45	9.65 331	25	9.70 247	31	0.29 753	9.95 084	15	7 16.8
46	9.65 356	25	9.70 278	31	0.29 722	9.95 078	14	8 19.2
47	9.65 381	25	9.70 309	32	0.29 691	9.95 071	13	9 21.6
48	9.65 406	25	9.70 341	31	0.29 659	9.95 065	12	
49	9.65 431	25	9.70 372	32	0.29 628	9.95 059	11	7 6
50	9.65 456	25	9.70 404	31	0.29 596	9.95 052	10	1 0.7 0.6
51	9.65 481	25	9.70 435	31	0.29 565	9.95 046	9	2 1.4 1.2
52	9.65 506	25	9.70 466	32	0.29 534	9.95 039	8	3 2.1 1.8
53	9.65 531	25	9.70 498	31	0.29 502	9.95 033	7	4 2.8 2.4
54	9.65 556	24	9.70 529	31	0.29 471	9.95 027	6	5 3.5 3.0
55	9.65 580	25	9.70 560	32	0.29 440	9.95 020	5	6 4.2 3.6
56	9.65 605	25	9.70 592	31	0.29 408	9.95 014	4	7 4.9 4.2
57	9.65 630	25	9.70 623	31	0.29 377	9.95 007	3	8 5.6 4.8
58	9.65 655	25	9.70 654	31	0.29 346	9.95 001	2	9 6.3 5.4
59	9.65 680	25	9.70 685	32	0.29 315	9.94 995	1	
60	9.65 705		9.70 717		0.29 283	9.94 988	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	333°... 153°
	L COS		L COT		L TAN	L SIN		243°... 63°

27°—, 207°—	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
117°—, 297°—	L COS		L COT		L TAN	L SIN		
0	9.65 705	24	9.70 717	31	0.29 283	9.94 988	60	
1	9.65 729	25	9.70 748	31	0.29 252	9.94 962	59	
2	9.65 754	25	9.70 779	31	0.29 221	9.94 975	58	
3	9.65 779	26	9.70 810	31	0.29 180	9.94 969	57	
4	9.65 804	24	8.70 841	32	0.29 169	9.94 982	58	32 31
6	9.65 828	25	8.70 873	31	0.29 127	9.94 958	56	1 3.2 3.1
8	9.65 853	25	9.70 804	31	0.29 096	9.94 949	54	2 8.4 6.2
7	9.65 878	24	9.70 935	31	0.29 065	9.94 943	53	3 9.8 8.3
8	9.65 902	25	9.70 966	31	0.29 034	9.94 936	52	4 12.8 12.4
9	9.65 927	25	8.70 997	31	0.29 003	9.94 930	51	5 16.0 16.5
10	9.65 952	24	9.71 028	31	0.28 972	9.94 923	50	6 19.2 18.6
11	9.65 976	25	9.71 059	31	0.28 941	9.94 917	49	7 22.4 21.7
12	9.66 001	24	9.71 090	31	0.28 910	9.94 911	48	8 25.6 24.6
13	9.66 025	25	9.71 121	32	0.28 879	9.94 904	47	9 28.8 27.9
14	9.66 050	25	9.71 153	31	0.28 847	9.94 898	46	
15	9.66 075	24	9.71 184	31	0.28 816	9.94 891	45	30
16	9.66 099	25	9.71 215	31	0.28 785	9.94 885	44	1 3.0
17	9.66 124	24	9.71 246	31	0.28 754	9.94 878	43	2 6.0
18	9.66 148	25	9.71 277	31	0.28 723	9.94 871	42	3 9.0
19	9.66 173	24	9.71 308	31	0.28 692	9.94 865	41	4 12.0
20	9.66 197	24	9.71 339	31	0.28 661	9.94 858	40	5 15.0
21	9.66 221	25	9.71 370	31	0.28 630	9.94 852	39	6 18.0
22	9.66 246	24	9.71 401	30	0.28 599	9.94 845	38	7 21.0
23	9.66 270	25	9.71 431	31	0.28 569	9.94 839	37	8 24.0
24	9.66 295	24	9.71 462	31	0.28 538	9.94 832	36	9 27.0
25	9.66 319	24	9.71 493	31	0.28 507	9.94 826	35	
26	9.66 343	25	9.71 524	31	0.28 476	9.94 819	34	25 24
27	9.66 368	24	9.71 555	31	0.28 445	9.94 813	33	1 2.5 2.4
28	9.66 392	24	9.71 586	31	0.28 414	9.94 806	32	2 5.0 4.3
29	9.66 416	25	9.71 617	31	0.28 383	9.94 799	31	3 7.5 7.2
30	9.66 441	24	9.71 648	31	0.28 352	9.94 793	30	4 10.0 9.6
31	9.66 465	24	9.71 679	30	0.28 321	9.94 786	29	5 12.5 12.0
32	9.66 489	24	9.71 709	31	0.28 291	9.94 780	28	6 15.0 14.4
33	9.66 513	24	9.71 740	31	0.28 260	9.94 773	27	7 17.5 16.6
34	9.66 537	25	9.71 771	31	0.28 229	9.94 767	26	8 20.0 19.2
35	9.66 562	24	9.71 802	31	0.28 198	9.94 760	25	9 22.5 21.6
36	9.66 586	24	9.71 833	30	0.28 167	9.94 753	24	
37	9.66 610	24	9.71 863	31	0.28 137	9.94 747	23	
38	9.66 634	24	9.71 894	31	0.28 106	9.94 740	22	23
39	9.66 658	24	9.71 925	30	0.28 075	9.94 734	21	1 2.3
40	9.66 682	24	9.71 955	31	0.28 045	9.94 727	20	2 4.6
41	9.66 706	25	9.71 986	31	0.28 014	9.94 720	19	3 6.9
42	9.66 731	24	9.72 017	31	0.27 983	9.94 714	18	4 9.2
43	9.66 755	24	9.72 048	30	0.27 952	9.94 707	17	5 11.5
44	9.66 779	24	9.72 078	31	0.27 922	9.94 700	16	6 13.8
45	9.66 803	24	9.72 109	31	0.27 891	9.94 694	15	7 16.1
46	9.66 827	24	9.72 140	30	0.27 860	9.94 687	14	8 18.4
47	9.66 851	24	9.72 170	31	0.27 830	9.94 680	13	9 20.7
48	9.66 875	24	9.72 201	30	0.27 799	9.94 674	12	
49	9.66 899	23	9.72 231	31	0.27 769	9.94 667	11	
50	9.66 922	24	9.72 262	31	0.27 738	9.94 660	10	7 6
51	9.66 946	24	9.72 293	30	0.27 707	9.94 654	9	1 0.7 0.6
52	9.66 970	24	9.72 323	31	0.27 677	9.94 647	8	2 1.4 1.2
53	9.66 994	24	9.72 354	30	0.27 646	9.94 640	7	3 2.1 1.8
54	9.67 018	24	9.72 384	31	0.27 616	9.94 634	6	4 2.8 2.4
55	9.67 042	24	9.72 415	30	0.27 585	9.94 627	5	5 3.5 3.0
56	9.67 066	24	9.72 445	31	0.27 555	9.94 620	4	6 4.2 3.6
57	9.67 090	23	9.72 476	30	0.27 524	9.94 614	3	7 4.9 4.2
58	9.67 113	24	9.72 506	31	0.27 494	9.94 607	2	8 5.6 4.8
59	9.67 137	24	9.72 537	30	0.27 463	9.94 600	1	9 6.3 5.4
60	9.67 161		9.72 567		0.27 433	9.94 593	0	
	L SIN	D	L TAN	CD	L COT	L COS	D	332°—, 153°—
	L COS		L COT		L TAN	L SIN		242°—, 62°—

28°... 208°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
118°... 298°...	L COS		L COT		L TAN	L SIN		
0	9.67 161	24	9.72 567	31	0.27 433	9.94 593	6	60
1	9.67 185	23	9.72 598	30	0.27 402	9.94 587	7	59
2	9.67 208	24	9.72 628	31	0.27 372	9.94 580	7	58
3	9.67 232	24	9.72 659	30	0.27 341	9.94 573	7	57
4	9.67 256	24	9.72 689	31	0.27 311	9.94 567	6	56
5	9.67 280	23	9.72 720	30	0.27 280	9.94 560	7	55
6	9.67 303	24	9.72 750	30	0.27 250	9.94 553	7	54
7	9.67 327	23	9.72 780	31	0.27 220	9.94 546	6	53
8	9.67 350	24	9.72 811	30	0.27 189	9.94 540	7	52
9	9.67 374	24	9.72 841	31	0.27 159	9.94 533	7	51
10	9.67 398	23	9.72 872	30	0.27 128	9.94 526	7	50
11	9.67 421	24	9.72 902	30	0.27 098	9.94 519	6	49
12	9.67 445	23	9.72 932	31	0.27 068	9.94 513	7	48
13	9.67 468	24	9.72 963	30	0.27 037	9.94 506	7	47
14	9.67 492	23	9.72 993	30	0.27 007	9.94 499	7	46
15	9.67 515	24	9.73 023	31	0.26 977	9.94 492	7	45
16	9.67 539	23	9.73 054	30	0.26 946	9.94 485	6	44
17	9.67 562	24	9.73 084	30	0.26 916	9.94 479	7	43
18	9.67 586	23	9.73 114	30	0.26 886	9.94 472	7	42
19	9.67 609	24	9.73 144	31	0.26 856	9.94 465	7	41
20	9.67 633	23	9.73 175	30	0.26 825	9.94 458	7	40
21	9.67 656	24	9.73 205	30	0.26 795	9.94 451	6	39
22	9.67 680	23	9.73 235	30	0.26 765	9.94 445	7	38
23	9.67 703	23	9.73 265	30	0.26 735	9.94 438	7	37
24	9.67 726	24	9.73 295	31	0.26 705	9.94 431	7	36
25	9.67 750	23	9.73 326	30	0.26 674	9.94 424	7	35
26	9.67 773	23	9.73 356	30	0.26 644	9.94 417	7	34
27	9.67 796	24	9.73 386	30	0.26 614	9.94 410	6	33
28	9.67 820	23	9.73 416	30	0.26 584	9.94 404	7	32
29	9.67 843	23	9.73 446	30	0.26 554	9.94 397	7	31
30	9.67 866	24	9.73 476	31	0.26 524	9.94 390	7	30
31	9.67 890	23	9.73 507	30	0.26 493	9.94 383	7	29
32	9.67 913	23	9.73 537	30	0.26 463	9.94 376	7	28
33	9.67 936	23	9.73 567	30	0.26 433	9.94 369	7	27
34	9.67 959	23	9.73 597	30	0.26 403	9.94 362	7	26
35	9.67 982	24	9.73 627	30	0.26 373	9.94 355	6	25
36	9.68 006	23	9.73 657	30	0.26 343	9.94 349	7	24
37	9.68 029	23	9.73 687	30	0.26 313	9.94 342	7	23
38	9.68 052	23	9.73 717	30	0.26 283	9.94 335	7	22
39	9.68 075	23	9.73 747	30	0.26 253	9.94 328	7	21
40	9.68 098	23	9.73 777	30	0.26 223	9.94 321	7	20
41	9.68 121	23	9.73 807	30	0.26 193	9.94 314	7	19
42	9.68 144	23	9.73 837	30	0.26 163	9.94 307	7	18
43	9.68 167	23	9.73 867	30	0.26 133	9.94 300	7	17
44	9.68 190	23	9.73 897	30	0.26 103	9.94 293	7	16
45	9.68 213	24	9.73 927	30	0.26 073	9.94 286	7	15
46	9.68 237	23	9.73 957	30	0.26 043	9.94 279	6	14
47	9.68 260	23	9.73 987	30	0.26 013	9.94 273	7	13
48	9.68 283	22	9.74 017	30	0.25 983	9.94 266	7	12
49	9.68 305	23	9.74 047	30	0.25 953	9.94 259	7	11
50	9.68 328	23	9.74 077	30	0.25 923	9.94 252	7	10
51	9.68 351	23	9.74 107	30	0.25 893	9.94 245	7	9
52	9.68 374	23	9.74 137	29	0.25 863	9.94 238	7	8
53	9.68 397	23	9.74 166	30	0.25 834	9.94 231	7	7
54	9.68 420	23	9.74 196	30	0.25 804	9.94 224	7	6
55	9.68 443	23	9.74 226	30	0.25 774	9.94 217	7	5
56	9.68 466	23	9.74 256	30	0.25 744	9.94 210	7	4
57	9.68 489	23	9.74 286	30	0.25 714	9.94 203	7	3
58	9.68 512	22	9.74 316	29	0.25 684	9.94 196	7	2
59	9.68 534	23	9.74 346	30	0.25 655	9.94 189	7	1
60	9.68 557		9.74 375		0.25 625	9.94 182		0
	L SIN	D	L TAN	CD	L COT	L COS	D	331°... 151°...
	L COS		L COT		L TAN	L SIN		241°... 61°...

29°... 209°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
119°... 299°...	L COS		L COT		L TAN	L SIN		
0	9.68 557	23	9.74 375	30	0.25 625	9.94 182	7	60
1	9.68 580	23	9.74 405	30	0.25 595	9.94 175	7	59
2	9.68 603	22	9.74 435	30	0.25 565	9.94 168	7	58
3	9.68 625	23	9.74 465	29	0.25 535	9.94 161	7	57
4	9.68 648	23	9.74 494	30	0.25 506	9.94 154	7	56
5	9.68 671	23	9.74 524	30	0.25 476	9.94 147	7	55
6	9.68 694	22	9.74 554	29	0.25 446	9.94 140	7	54
7	9.68 716	23	9.74 583	30	0.25 417	9.94 133	7	53
8	9.68 739	23	9.74 613	30	0.25 387	9.94 126	7	52
9	9.68 762	22	9.74 643	30	0.25 357	9.94 119	7	51
10	9.68 784	23	9.74 673	29	0.25 327	9.94 112	7	50
11	9.68 807	22	9.74 702	30	0.25 298	9.94 105	7	49
12	9.68 829	23	9.74 732	30	0.25 268	9.94 098	8	48
13	9.68 852	23	9.74 762	29	0.25 238	9.94 090	7	47
14	9.68 875	22	9.74 791	30	0.25 209	9.94 083	7	46
15	9.68 897	23	9.74 821	30	0.25 179	9.94 076	7	45
16	9.68 920	22	9.74 851	29	0.25 149	9.94 069	7	44
17	9.68 942	23	9.74 880	30	0.25 120	9.94 062	7	43
18	9.68 965	22	9.74 910	29	0.25 090	9.94 055	7	42
19	9.68 987	23	9.74 939	30	0.25 061	9.94 048	7	41
20	9.69 010	22	9.74 969	29	0.25 031	9.94 041	7	40
21	9.69 032	23	9.74 998	30	0.25 002	9.94 034	7	39
22	9.69 055	22	9.75 028	30	0.24 972	9.94 027	7	38
23	9.69 077	23	9.75 058	29	0.24 942	9.94 020	8	37
24	9.69 100	22	9.75 087	30	0.24 913	9.94 012	7	36
25	9.69 122	22	9.75 117	29	0.24 883	9.94 005	7	35
26	9.69 144	23	9.75 146	30	0.24 854	9.93 998	7	34
27	9.69 167	22	9.75 176	29	0.24 824	9.93 991	7	33
28	9.69 189	23	9.75 205	30	0.24 795	9.93 984	7	32
29	9.69 212	22	9.75 235	29	0.24 765	9.93 977	7	31
30	9.69 234	22	9.75 264	30	0.24 736	9.93 970	7	30
31	9.69 256	23	9.75 294	29	0.24 706	9.93 963	8	29
32	9.69 279	22	9.75 323	30	0.24 677	9.93 955	7	28
33	9.69 301	22	9.75 353	29	0.24 647	9.93 948	7	27
34	9.69 323	22	9.75 382	29	0.24 618	9.93 941	7	26
35	9.69 345	23	9.75 411	30	0.24 589	9.93 934	7	25
36	9.69 368	22	9.75 441	29	0.24 559	9.93 927	7	24
37	9.69 390	22	9.75 470	30	0.24 530	9.93 920	8	23
38	9.69 412	22	9.75 500	29	0.24 500	9.93 912	7	22
39	9.69 434	22	9.75 529	29	0.24 471	9.93 905	7	21
40	9.69 456	23	9.75 558	30	0.24 442	9.93 898	7	20
41	9.69 479	22	9.75 588	29	0.24 412	9.93 891	7	19
42	9.69 501	22	9.75 617	30	0.24 383	9.93 884	8	18
43	9.69 523	22	9.75 647	29	0.24 353	9.93 876	7	17
44	9.69 545	22	9.75 676	29	0.24 324	9.93 869	7	16
45	9.69 567	22	9.75 705	30	0.24 295	9.93 862	7	15
46	9.69 589	22	9.75 735	29	0.24 265	9.93 855	8	14
47	9.69 611	22	9.75 764	29	0.24 236	9.93 847	7	13
48	9.69 633	22	9.75 793	29	0.24 207	9.93 840	7	12
49	9.69 655	22	9.75 822	30	0.24 178	9.93 833	7	11
50	9.69 677	22	9.75 852	29	0.24 148	9.93 826	7	10
51	9.69 699	22	9.75 881	29	0.24 119	9.93 819	8	9
52	9.69 721	22	9.75 910	29	0.24 090	9.93 811	7	8
53	9.69 743	22	9.75 939	30	0.24 061	9.93 804	7	7
54	9.69 765	22	9.75 969	29	0.24 031	9.93 797	8	6
55	9.69 787	22	9.75 998	29	0.24 002	9.93 789	7	5
56	9.69 809	22	9.76 027	29	0.23 973	9.93 782	7	4
57	9.69 831	22	9.76 056	30	0.23 944	9.93 775	7	3
58	9.69 853	22	9.76 088	29	0.23 914	9.93 768	8	2
59	9.69 875	22	9.76 115	29	0.23 885	9.93 760	7	1
60	9.69 897		9.76 144		0.23 856	9.93 753		0
	L SIN	D	L TAN	CD	L COT	L COS	D	330°... 150°...
	L COS		L COT		L TAN	L SIN		240°... 60°...

30°... 210°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
120°... 300°	L COS		L COT		L TAN	L SIN		
0	9.69 897	22	9.76 144	29	0.23 856	9.93 753	7	60
1	9.69 919	22	9.76 173	29	0.23 827	9.93 746	8	59
2	9.69 941	22	9.76 202	29	0.23 798	9.93 738	7	58
3	9.69 963	22	9.76 231	30	0.23 769	9.93 731	7	57
4	9.69 984	22	9.76 261	29	0.23 739	9.93 724	7	56
5	9.70 006	22	9.76 290	29	0.23 710	9.93 717	8	55
6	9.70 028	22	9.76 319	29	0.23 681	9.93 709	7	54
7	9.70 050	22	9.76 348	29	0.23 652	9.93 702	7	53
8	9.70 072	21	9.76 377	29	0.23 623	9.93 695	8	52
9	9.70 093	22	9.76 406	29	0.23 594	9.93 687	7	51
10	9.70 115	22	9.76 435	29	0.23 565	9.93 680	7	50
11	9.70 137	22	9.76 464	29	0.23 536	9.93 673	8	49
12	9.70 159	21	9.76 493	29	0.23 507	9.93 665	7	48
13	9.70 180	22	9.76 522	29	0.23 478	9.93 658	8	47
14	9.70 202	22	9.76 551	29	0.23 449	9.93 650	7	46
15	9.70 224	21	9.76 580	29	0.23 420	9.93 643	7	45
16	9.70 245	22	9.76 609	30	0.23 391	9.93 636	8	44
17	9.70 267	21	9.76 639	29	0.23 361	9.93 628	7	43
18	9.70 288	22	9.76 668	29	0.23 332	9.93 621	7	42
19	9.70 310	22	9.76 697	28	0.23 303	9.93 614	8	41
20	9.70 332	21	9.76 725	29	0.23 275	9.93 606	7	40
21	9.70 353	22	9.76 754	29	0.23 246	9.93 599	8	39
22	9.70 375	22	9.76 783	29	0.23 217	9.93 591	8	38
23	9.70 396	21	9.76 812	29	0.23 188	9.93 584	7	37
24	9.70 418	21	9.76 841	29	0.23 159	9.93 577	8	36
25	9.70 439	22	9.76 870	29	0.23 130	9.93 569	7	35
26	9.70 461	21	9.76 899	29	0.23 101	9.93 562	8	34
27	9.70 482	22	9.76 928	29	0.23 072	9.93 554	7	33
28	9.70 504	21	9.76 957	29	0.23 043	9.93 547	8	32
29	9.70 525	22	9.78 986	29	0.23 014	9.93 539	7	31
30	9.70 547	21	9.77 015	29	0.22 985	9.93 532	7	30
31	9.70 568	22	9.77 044	29	0.22 956	9.93 525	8	29
32	9.70 590	21	9.77 073	28	0.22 927	9.93 517	7	28
33	9.70 611	22	9.77 101	29	0.22 899	9.93 510	8	27
34	9.70 633	21	9.77 130	29	0.22 870	9.93 502	7	26
35	9.70 654	21	9.77 159	29	0.22 841	9.93 495	8	25
36	9.70 675	22	9.77 188	29	0.22 812	9.93 487	7	24
37	9.70 697	21	9.77 217	29	0.22 783	9.93 480	8	23
38	9.70 718	21	9.77 246	28	0.22 754	9.93 472	7	22
39	9.70 739	22	9.77 274	29	0.22 726	9.93 465	8	21
40	9.70 761	21	9.77 303	29	0.22 697	9.93 457	7	20
41	9.70 782	21	9.77 332	29	0.22 668	9.93 450	8	19
42	9.70 803	21	9.77 361	29	0.22 639	9.93 442	7	18
43	9.70 824	22	9.77 390	28	0.22 610	9.93 435	8	17
44	9.70 846	21	9.77 418	29	0.22 582	9.93 427	7	16
45	9.70 867	21	9.77 447	29	0.22 553	9.93 420	8	15
46	9.70 888	21	9.77 476	29	0.22 524	9.93 412	7	14
47	9.70 909	22	9.77 505	28	0.22 495	9.93 405	8	13
48	9.70 931	21	9.77 533	29	0.22 467	9.93 397	7	12
49	9.70 952	21	9.77 562	29	0.22 438	9.93 390	8	11
50	9.70 973	21	9.77 591	28	0.22 409	9.93 382	7	10
51	9.70 994	21	9.77 619	29	0.22 381	9.93 375	8	9
52	9.71 015	21	9.77 648	29	0.22 352	9.93 367	7	8
53	9.71 036	22	9.77 677	29	0.22 323	9.93 360	8	7
54	9.71 058	21	9.77 706	28	0.22 294	9.93 352	7	6
55	9.71 079	21	9.77 734	29	0.22 266	9.93 344	8	5
56	9.71 100	21	9.77 763	28	0.22 237	9.93 337	7	4
57	9.71 121	21	9.77 791	29	0.22 209	9.93 329	8	3
58	9.71 142	21	9.77 820	29	0.22 180	9.93 322	7	2
59	9.71 163	21	9.77 849	28	0.22 151	9.93 314	8	1
60	9.71 184		9.77 877		0.22 123	9.93 307		0
	L SIN	D	L TAN	CD	L COT	L COS	D	329°... 149°
	L COS		L COT		L TAN	L SIN		239°... 59°

31°... 211°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
121°... 301°	L COS		L COT		L TAN	L SIN		
0	9.71 184	21	9.77 877	29	0.22 123	9.93 307	8	60
1	9.71 205	21	9.77 906	29	0.22 094	9.93 299	8	59
2	9.71 226	21	9.77 935	28	0.22 085	9.93 291	7	58
3	9.71 247	21	9.77 963	29	0.22 037	9.93 284	8	57
4	9.71 268	21	9.77 992	28	0.22 008	9.93 278	7	56
5	9.71 289	21	9.78 020	29	0.21 980	9.93 269	8	55
6	9.71 310	21	9.78 049	28	0.21 951	9.93 261	8	54
7	9.71 331	21	9.78 077	29	0.21 923	9.93 253	7	53
8	9.71 352	21	9.78 106	29	0.21 894	9.93 246	8	52
9	9.71 373	20	9.78 135	28	0.21 865	9.93 238	8	51
10	9.71 393	21	9.78 163	29	0.21 837	9.93 230	7	50
11	9.71 414	21	9.78 192	28	0.21 808	9.93 223	8	49
12	9.71 435	21	9.78 220	29	0.21 780	9.93 216	8	48
13	9.71 456	21	9.78 249	28	0.21 751	9.93 207	7	47
14	9.71 477	21	9.78 277	29	0.21 723	9.93 200	8	46
15	9.71 498	21	9.78 306	28	0.21 694	9.93 192	8	45
16	9.71 519	20	9.78 334	29	0.21 666	9.93 184	7	44
17	9.71 539	21	9.78 363	28	0.21 637	9.93 177	8	43
18	9.71 560	21	9.78 391	28	0.21 609	9.93 169	8	42
19	9.71 581	21	9.78 419	29	0.21 581	9.93 161	7	41
20	9.71 602	20	9.78 448	28	0.21 552	9.93 154	8	40
21	9.71 622	21	9.78 476	29	0.21 524	9.93 146	8	39
22	9.71 643	21	9.78 505	28	0.21 495	9.93 138	7	38
23	9.71 664	21	9.78 533	29	0.21 467	9.93 131	8	37
24	9.71 685	20	9.78 562	28	0.21 438	9.93 123	8	36
25	9.71 705	21	9.78 590	28	0.21 410	9.93 115	7	35
26	9.71 726	21	9.78 618	29	0.21 382	9.93 108	8	34
27	9.71 747	20	9.78 647	28	0.21 353	9.93 100	8	33
28	9.71 767	21	9.78 675	29	0.21 325	9.93 092	8	32
29	9.71 788	21	9.78 704	28	0.21 296	9.93 084	7	31
30	9.71 809	20	9.78 732	28	0.21 268	9.93 077	8	30
31	9.71 829	21	9.78 760	29	0.21 240	9.93 069	8	29
32	9.71 850	20	9.78 789	28	0.21 211	9.93 061	8	28
33	9.71 870	21	9.78 817	28	0.21 183	9.93 053	7	27
34	9.71 891	20	9.78 845	29	0.21 155	9.93 046	8	26
35	9.71 911	21	9.78 874	28	0.21 126	9.93 038	8	25
36	9.71 932	20	9.78 902	28	0.21 098	9.93 030	8	24
37	9.71 952	21	9.78 930	29	0.21 070	9.93 022	8	23
38	9.71 973	21	9.78 959	28	0.21 041	9.93 014	7	22
39	9.71 994	20	9.78 987	28	0.21 013	9.93 007	8	21
40	9.72 014	20	9.79 015	28	0.20 985	9.92 999	8	20
41	9.72 034	21	9.79 043	29	0.20 957	9.92 991	8	19
42	9.72 055	20	9.79 072	28	0.20 928	9.92 983	7	18
43	9.72 075	21	9.79 100	28	0.20 900	9.92 978	8	17
44	9.72 096	20	9.79 128	28	0.20 872	9.92 968	8	16
45	9.72 116	21	9.79 156	29	0.20 844	9.92 960	8	15
46	9.72 137	20	9.79 185	28	0.20 815	9.92 952	8	14
47	9.72 157	20	9.79 213	28	0.20 787	9.92 944	8	13
48	9.72 177	21	9.79 241	28	0.20 759	9.92 936	7	12
49	9.72 198	20	9.79 269	28	0.20 731	9.92 929	8	11
50	9.72 218	20	9.79 297	29	0.20 703	9.92 921	8	10
51	9.72 238	21	9.79 326	28	0.20 674	9.92 913	8	9
52	9.72 259	20	9.79 354	28	0.20 646	9.92 905	8	8
53	9.72 279	20	9.79 382	28	0.20 618	9.92 897	7	7
54	9.72 299	21	9.79 410	28	0.20 590	9.92 889	8	6
55	9.72 320	20	9.79 438	28	0.20 562	9.92 881	7	5
56	9.72 340	20	9.79 466	29	0.20 534	9.92 874	8	4
57	9.72 360	21	9.79 495	28	0.20 505	9.92 868	8	3
58	9.72 381	20	9.79 523	28	0.20 477	9.92 858	8	2
59	9.72 401	20	9.79 551	28	0.20 449	9.92 850	8	1
60	9.72 421		9.79 579		0.20 421	9.92 842		0
	L SIN	D	L TAN	CD	L COT	L COS	D	328°... 148°
	L COS		L COT		L TAN	L SIN		238°... 58°

32°—, 212°—	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
122°—, 302°—	L COS		L COT		L TAN	L SIN		
0	9.72 421	20	9.79 579	28	0.20 421	9.92 842	8	60
1	9.72 441	20	9.79 607	28	0.20 393	9.92 834	8	59
2	9.72 461	21	9.79 635	28	0.20 365	9.92 826	8	58
3	9.72 482	20	9.79 663	28	0.20 337	9.92 818	8	57
4	9.72 502	20	9.79 691	28	0.20 309	9.92 810	7	56
5	9.72 522	20	9.79 719	28	0.20 281	9.92 803	8	55
6	9.72 542	20	9.79 747	29	0.20 253	9.92 795	8	54
7	9.72 562	20	9.79 776	28	0.20 224	9.92 787	8	53
8	9.72 582	20	9.79 804	28	0.20 196	9.92 779	8	52
9	9.72 602	20	9.79 832	28	0.20 168	9.92 771	8	51
10	9.72 622	21	9.79 860	28	0.20 140	9.92 763	8	50
11	9.72 643	20	9.79 888	28	0.20 112	9.92 755	8	49
12	9.72 663	20	9.79 916	28	0.20 084	9.92 747	8	48
13	9.72 683	20	9.79 944	28	0.20 056	9.92 739	8	47
14	9.72 703	20	9.79 972	28	0.20 028	9.92 731	8	46
15	9.72 723	20	9.80 000	28	0.20 000	9.92 723	8	45
16	9.72 743	20	9.80 028	28	0.19 972	9.92 715	8	44
17	9.72 763	20	9.80 056	28	0.19 944	9.92 707	8	43
18	9.72 783	20	9.80 084	28	0.19 916	9.92 699	8	42
19	9.72 803	20	9.80 112	28	0.19 888	9.92 691	8	41
20	9.72 823	20	9.80 140	28	0.19 860	9.92 683	8	40
21	9.72 843	20	9.80 168	27	0.19 832	9.92 675	8	39
22	9.72 863	20	9.80 195	28	0.19 805	9.92 667	8	38
23	9.72 883	19	9.80 223	28	0.19 777	9.92 659	8	37
24	9.72 902	20	9.80 251	28	0.19 749	9.92 651	8	36
25	9.72 922	20	9.80 279	28	0.19 721	9.92 643	8	35
26	9.72 942	20	9.80 307	28	0.19 693	9.92 635	8	34
27	9.72 962	20	9.80 335	28	0.19 665	9.92 627	8	33
28	9.72 982	20	9.80 363	28	0.19 637	9.92 619	8	32
29	9.73 002	20	9.80 391	28	0.19 609	9.92 611	8	31
30	9.73 022	19	9.80 419	28	0.19 581	9.92 603	8	30
31	9.73 041	20	9.80 447	27	0.19 553	9.92 595	8	29
32	9.73 061	20	9.80 474	28	0.19 526	9.92 587	8	28
33	9.73 081	20	9.80 502	28	0.19 498	9.92 579	8	27
34	9.73 101	20	9.80 530	28	0.19 470	9.92 571	8	26
35	9.73 121	19	9.80 558	28	0.19 442	9.92 563	8	25
36	9.73 140	20	9.80 586	28	0.19 414	9.92 555	9	24
37	9.73 160	20	9.80 614	28	0.19 386	9.92 546	8	23
38	9.73 180	20	9.80 642	27	0.19 358	9.92 538	8	22
39	9.73 200	19	9.80 669	28	0.19 331	9.92 530	8	21
40	9.73 219	20	9.80 697	28	0.19 303	9.92 522	8	20
41	9.73 239	20	9.80 725	28	0.19 275	9.92 514	8	19
42	9.73 259	19	9.80 753	28	0.19 247	9.92 506	8	18
43	9.73 278	20	9.80 781	27	0.19 219	9.92 498	8	17
44	9.73 298	20	9.80 808	28	0.19 192	9.92 490	8	16
45	9.73 318	19	9.80 836	28	0.19 164	9.92 482	9	15
46	9.73 337	20	9.80 864	28	0.19 136	9.92 473	8	14
47	9.73 357	20	9.80 892	27	0.19 108	9.92 465	8	13
48	9.73 377	19	9.80 919	28	0.19 081	9.92 457	8	12
49	9.73 396	20	9.80 947	28	0.19 053	9.92 449	8	11
50	9.73 416	19	9.80 975	28	0.19 025	9.92 441	8	10
51	9.73 435	20	9.81 003	27	0.18 997	9.92 433	8	9
52	9.73 455	19	9.81 030	28	0.18 970	9.92 425	9	8
53	9.73 474	20	9.81 058	28	0.18 942	9.92 416	8	7
54	9.73 494	19	9.81 086	27	0.18 914	9.92 408	8	6
55	9.73 513	20	9.81 113	28	0.18 887	9.92 400	8	5
56	9.73 533	19	9.81 141	28	0.18 859	9.92 392	8	4
57	9.73 552	20	9.81 169	27	0.18 831	9.92 384	8	3
58	9.73 572	19	9.81 196	28	0.18 804	9.92 376	9	2
59	9.73 591	20	9.81 224	28	0.18 776	9.92 367	8	1
60	9.73 611		9.81 252		0.18 748	9.92 359		0
	L SIN	D	L TAN	CD	L COT	L COS	D	227°—, 147°—
	L COS		L COT		L TAN	L SIN		237°—, 57°—

33°... 212°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
123°... 303°	L COS		L COT		L TAN	L SIN		
0	9.73 611	19	9.81 252	27	0.18 748	9.92 359	8	60
1	9.73 630	20	9.81 279	28	0.18 721	9.92 351	8	59
2	9.73 650	19	9.81 307	28	0.18 693	9.92 343	8	58
3	9.73 669	20	9.81 335	27	0.18 665	9.92 335	9	57
4	9.73 689	19	9.81 362	28	0.18 638	9.92 326	8	56
5	9.73 708	19	9.81 390	28	0.18 610	9.92 318	8	55
6	9.73 727	20	9.81 418	27	0.18 582	9.92 310	8	54
7	9.73 747	19	9.81 445	28	0.18 555	9.92 302	9	53
8	9.73 766	19	9.81 473	27	0.18 527	9.92 293	8	52
9	9.73 785	20	9.81 500	28	0.18 500	9.92 285	8	51
10	9.73 805	19	9.81 528	28	0.18 472	9.92 277	8	50
11	9.73 824	19	9.81 556	27	0.18 444	9.92 269	9	49
12	9.73 843	20	9.81 583	28	0.18 417	9.92 260	8	48
13	9.73 863	19	9.81 611	27	0.18 389	9.92 252	8	47
14	9.73 882	19	9.81 638	28	0.18 362	9.92 244	9	46
15	9.73 901	20	9.81 666	27	0.18 334	9.92 235	8	45
16	9.73 921	19	9.81 693	28	0.18 307	9.92 227	8	44
17	9.73 940	19	9.81 721	27	0.18 279	9.92 219	8	43
18	9.73 959	19	9.81 748	28	0.18 252	9.92 211	9	42
19	9.73 978	19	9.81 776	27	0.18 224	9.92 202	8	41
20	9.73 997	20	9.81 803	28	0.18 197	9.92 194	8	40
21	9.74 017	19	9.81 831	27	0.18 169	9.92 186	9	39
22	9.74 036	19	9.81 858	28	0.18 142	9.92 177	8	38
23	9.74 055	19	9.81 886	27	0.18 114	9.92 169	8	37
24	9.74 074	19	9.81 913	28	0.18 087	9.92 161	9	36
25	9.74 093	20	9.81 941	27	0.18 059	9.92 152	8	35
26	9.74 113	19	9.81 968	28	0.18 032	9.92 144	8	34
27	9.74 132	19	9.81 996	27	0.18 004	9.92 136	9	33
28	9.74 151	19	9.82 023	28	0.17 977	9.92 127	8	32
29	9.74 170	19	9.82 051	27	0.17 949	9.92 119	8	31
30	9.74 189	19	9.82 078	28	0.17 922	9.92 111	9	30
31	9.74 208	19	9.82 106	27	0.17 894	9.92 102	8	29
32	9.74 227	19	9.82 133	28	0.17 867	9.92 094	8	28
33	9.74 246	19	9.82 161	27	0.17 839	9.92 086	9	27
34	9.74 265	19	9.82 188	27	0.17 812	9.92 077	8	26
35	9.74 284	19	9.82 215	28	0.17 785	9.92 069	9	25
36	9.74 303	19	9.82 243	27	0.17 757	9.92 060	8	24
37	9.74 322	19	9.82 270	28	0.17 730	9.92 052	8	23
38	9.74 341	19	9.82 298	27	0.17 702	9.92 044	9	22
39	9.74 360	19	9.82 325	27	0.17 675	9.92 035	8	21
40	9.74 379	19	9.82 352	28	0.17 648	9.92 027	9	20
41	9.74 398	19	9.82 380	27	0.17 620	9.92 018	8	19
42	9.74 417	19	9.82 407	28	0.17 593	9.92 010	8	18
43	9.74 436	19	9.82 435	27	0.17 565	9.92 002	9	17
44	9.74 455	19	9.82 462	27	0.17 538	9.91 993	8	16
45	9.74 474	19	9.82 489	28	0.17 511	9.91 985	9	15
46	9.74 493	19	9.82 517	27	0.17 483	9.91 976	8	14
47	9.74 512	19	9.82 544	27	0.17 456	9.91 968	9	13
48	9.74 531	18	9.82 571	28	0.17 429	9.91 959	8	12
49	9.74 549	19	9.82 599	27	0.17 401	9.91 951	9	11
50	9.74 568	19	9.82 626	27	0.17 374	9.91 942	8	10
51	9.74 587	19	9.82 653	28	0.17 347	9.91 934	9	9
52	9.74 606	19	9.82 681	27	0.17 319	9.91 925	8	8
53	9.74 625	19	9.82 708	27	0.17 292	9.91 917	9	7
54	9.74 644	18	9.82 735	27	0.17 265	9.91 908	8	6
55	9.74 662	19	9.82 762	28	0.17 238	9.91 900	9	5
56	9.74 681	19	9.82 790	27	0.17 210	9.91 891	8	4
57	9.74 700	19	9.82 817	27	0.17 183	9.91 883	9	3
58	9.74 719	18	9.82 844	27	0.17 156	9.91 874	8	2
59	9.74 737	19	9.82 871	28	0.17 129	9.91 866	9	1
60	9.74 756		9.82 899		0.17 101	9.91 857		0
	L SIN	D	L TAN	CD	L COT	L COS	D	326°... 146°
	L COS		L COT		L TAN	L SIN		236°... 50°

34°—, 214°—	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
124°—, 304°—	L COS		L COT		L TAN	L SIN		
0	9.74 765	19	9.82 899	27	0.17 101	9.91 857	8	60
1	9.74 775	19	9.82 928	27	0.17 074	9.91 849	9	59
2	9.74 794	18	9.82 953	27	0.17 047	9.91 840	8	58
3	9.74 812	19	9.82 980	28	0.17 020	9.91 832	8	57
4	8.74 831	19	9.83 008	27	0.18 992	9.91 823	8	58
5	9.74 850	18	9.83 035	27	0.15 956	9.91 815	9	55
6	9.74 868	19	9.83 062	27	0.15 938	9.91 806	8	54
7	9.74 887	19	9.83 089	28	0.18 911	9.91 798	9	53
8	9.74 908	18	9.83 117	27	0.18 883	9.91 789	8	52
9	9.74 924	19	9.83 144	27	0.18 856	9.91 781	9	51
10	9.74 943	18	9.83 171	27	0.15 829	9.91 772	9	50
11	9.74 981	19	9.83 198	27	0.16 802	9.91 763	8	49
12	9.74 980	19	9.83 225	27	0.15 775	9.91 755	9	48
13	9.74 999	18	9.83 252	28	0.15 748	9.91 746	8	47
14	9.75 017	19	9.83 280	27	0.15 720	9.91 738	9	45
15	9.75 035	18	9.83 307	27	0.15 693	9.91 729	9	45
16	9.75 054	19	9.83 334	27	0.15 666	9.91 720	8	44
17	9.75 073	18	9.83 361	27	0.15 639	9.91 712	9	43
18	9.75 091	19	9.83 388	27	0.16 612	9.91 703	8	42
19	9.75 110	18	9.83 415	27	0.18 585	9.91 695	9	41
20	9.75 128	19	9.83 442	28	0.18 558	9.91 686	9	40
21	9.75 147	18	9.83 470	27	0.16 530	9.91 677	8	39
22	9.75 185	19	9.83 497	27	0.18 503	9.91 669	9	38
23	9.75 184	18	9.83 524	27	0.15 478	9.91 660	9	37
24	9.75 202	19	9.83 551	27	0.18 449	9.91 651	8	36
25	9.75 221	18	9.83 578	27	0.18 422	9.91 643	9	35
26	9.75 239	19	9.83 605	27	0.15 395	9.91 634	9	34
27	9.75 258	18	9.83 632	27	0.15 368	9.91 625	8	33
28	9.75 275	18	9.83 659	27	0.16 341	9.91 617	9	32
29	9.75 294	19	9.83 688	27	0.15 314	9.91 608	9	31
30	9.75 313	18	9.83 713	27	0.16 287	9.91 599	6	30
31	9.75 331	19	9.83 740	28	0.16 260	9.91 591	9	29
32	9.75 350	18	9.83 768	27	0.15 232	9.91 582	9	28
33	9.75 368	18	9.83 795	27	0.18 205	9.91 573	8	27
34	9.75 388	19	9.83 822	27	0.16 178	9.91 565	9	26
35	9.75 405	18	9.83 849	27	0.15 151	9.91 555	9	25
36	9.75 423	18	9.83 878	27	0.15 124	9.91 547	9	24
37	9.75 441	18	9.83 903	27	0.16 097	9.91 538	8	23
38	9.75 459	19	9.83 930	27	0.15 070	9.91 530	9	22
39	9.75 478	18	9.83 957	27	0.18 043	9.91 521	9	21
40	9.75 495	18	9.83 984	27	0.18 015	9.91 512	6	20
41	9.75 514	19	9.84 011	27	0.15 989	9.91 504	9	19
42	9.75 533	18	9.84 038	27	0.15 962	9.91 495	9	18
43	9.75 551	18	9.84 055	27	0.15 935	9.91 486	9	17
44	9.75 569	18	9.84 092	27	0.15 908	9.91 477	6	15
45	9.75 587	18	9.84 119	27	0.15 881	9.91 469	9	15
46	9.75 605	19	9.84 145	27	0.15 854	9.91 460	9	14
47	9.75 624	18	9.84 173	27	0.15 827	9.91 451	9	13
48	9.75 642	18	9.84 200	27	0.15 800	9.91 442	9	12
49	9.75 660	18	9.84 227	27	0.15 773	9.91 433	8	11
50	9.75 678	18	9.84 284	26	0.15 746	9.91 425	9	10
51	9.75 695	18	9.84 280	27	0.15 720	9.91 415	9	9
52	9.75 714	19	9.84 307	27	0.15 693	9.91 407	9	8
53	9.75 733	18	9.84 334	27	0.15 666	9.91 398	9	7
54	9.75 751	18	9.84 361	27	0.15 639	9.91 389	8	4
55	9.75 769	18	9.84 388	27	0.15 612	9.91 381	9	5
56	9.75 787	18	9.84 415	27	0.15 585	9.91 372	9	5
57	9.75 805	18	9.84 442	27	0.15 558	9.91 363	9	4
58	9.75 823	18	9.84 469	27	0.15 531	9.91 354	9	3
59	9.75 841	18	9.84 496	27	0.15 504	9.91 345	9	2
60	9.75 859		9.84 523		0.15 477	9.91 338		0
	L SIN	D	L TAN	CD	L COT	L COS	D	325°—, 145°—
	L COS		L COT		L TAN	L SIN		235°—, 55°—

35°... 215°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
125°... 305°...	L COS		L COT		L TAN	L SIN		
0	9.75 859	18	9.84 523	27	0.15 477	9.91 336	8	60
1	9.75 877	18	9.84 550	27	0.15 460	9.91 328	9	59
2	9.75 895	18	9.84 576	26	0.15 424	9.91 319	9	58
3	9.75 813	18	9.84 603	27	0.16 397	9.81 310	9	57
4	9.75 931	18	9.84 630	27	0.15 370	9.91 301	9	58
5	9.75 949	18	9.84 657	27	0.15 343	9.91 292	9	55
6	9.75 967	18	9.84 684	27	0.16 318	9.91 283	9	54
7	9.76 985	18	9.84 711	27	0.15 289	9.91 274	8	53
8	9.76 003	18	9.84 738	26	0.15 262	9.91 266	9	62
9	9.76 021	18	8.84 764	27	0.16 238	8.81 257	9	61
10	9.76 039	18	9.84 791	27	0.15 209	9.91 248	9	50
11	9.76 057	18	9.84 818	27	0.15 182	9.91 239	9	49
12	9.76 075	18	8.84 845	27	0.15 155	9.91 230	9	48
13	9.76 093	18	9.84 872	27	0.15 128	9.81 221	9	47
14	9.78 111	18	8.84 899	26	0.15 101	9.91 212	9	48
15	9.76 129	17	9.84 925	27	0.15 075	9.91 203	9	45
16	9.76 146	18	9.84 952	27	0.15 048	9.91 194	9	44
17	9.76 164	18	9.84 979	27	0.15 021	9.91 185	9	43
18	9.76 182	18	9.85 006	27	0.14 994	9.91 176	8	42
19	9.78 200	18	8.85 033	28	0.14 987	9.91 187	8	41
20	9.76 218	18	9.85 059	27	0.14 941	9.91 158	9	40
21	9.76 238	17	9.85 086	27	0.14 914	9.91 149	8	39
22	9.76 253	18	9.85 113	27	0.14 887	9.91 141	9	38
23	9.76 271	18	9.86 140	28	0.14 860	9.91 132	9	37
24	9.78 289	18	9.85 166	27	0.14 834	9.91 123	9	36
25	9.76 307	17	9.85 193	27	0.14 807	9.91 114	9	35
26	9.76 324	18	9.85 220	27	0.14 780	9.91 105	9	34
27	9.76 342	18	9.85 247	26	0.14 753	9.91 098	9	33
28	9.76 360	18	9.85 273	27	0.14 727	9.91 087	8	32
29	9.76 378	17	9.85 300	27	0.14 700	9.91 078	9	31
30	9.76 395	18	9.85 327	27	0.14 673	9.91 069	9	30
31	9.76 413	18	9.85 354	26	0.14 646	9.91 060	9	29
32	9.78 431	17	9.85 380	27	0.14 620	9.91 051	9	28
33	9.78 448	18	9.85 407	27	0.14 593	9.91 042	9	27
34	9.76 466	18	8.85 434	26	0.14 566	9.91 033	10	26
35	9.76 484	17	9.85 460	27	0.14 540	9.91 023	9	25
36	9.78 501	18	9.85 487	27	0.14 613	9.91 014	9	24
37	9.78 519	18	9.85 514	26	0.14 486	9.91 005	9	23
38	9.76 537	17	9.85 540	27	0.14 460	9.90 996	9	22
39	9.78 554	18	9.85 567	27	0.14 433	9.90 987	9	21
40	9.78 572	18	9.85 594	28	0.14 406	9.90 978	9	20
41	9.76 590	17	9.85 620	27	0.14 380	9.90 969	9	19
42	9.78 607	18	9.85 647	27	0.14 353	9.90 960	9	18
43	9.76 625	17	9.85 674	26	0.14 326	9.90 951	9	17
44	9.76 642	18	9.85 700	27	0.14 300	9.90 942	9	16
45	9.76 660	17	9.85 727	27	0.14 273	9.90 933	9	15
46	9.76 677	18	9.85 754	26	0.14 246	9.90 924	9	14
47	9.76 695	17	9.85 780	27	0.14 220	9.90 915	9	13
48	9.76 712	17	9.85 807	27	0.14 193	9.90 906	9	12
49	9.76 730	17	9.85 834	26	0.14 166	9.90 898	10	11
50	9.76 747	18	9.85 860	27	0.14 140	9.90 887	9	10
51	9.76 765	17	9.85 887	26	0.14 113	9.90 878	9	9
52	9.78 782	18	9.85 913	27	0.14 087	9.90 869	9	8
53	9.76 800	17	9.85 940	27	0.14 060	9.90 860	9	7
54	9.76 817	18	9.85 967	26	0.14 033	9.90 851	9	6
55	9.78 835	17	9.85 993	27	0.14 007	9.90 842	10	5
56	9.76 852	18	9.86 020	26	0.13 980	9.90 832	9	4
57	9.78 870	17	9.88 048	27	0.13 954	9.90 823	9	3
58	9.78 887	17	9.86 073	27	0.13 927	9.90 814	9	2
59	9.76 904	18	9.86 100	26	0.13 900	9.90 806	9	1
60	8.78 922		9.86 126		0.13 874	9.90 798		0
	L SIN	D	L TAN	CD	L COT	L COS	D	324°... 144°...
	L COS		L COT		L TAN	L SIN		234°... 54°...

36°... 216°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
126°... 306°	L COS		L COT		L TAN	L SIN		
0	9.76 922	17	9.86 126	27	0.13 874	9.90 798	9	60
1	9.76 939	18	9.86 153	26	0.13 847	9.90 787	10	59
2	9.76 957	17	9.86 179	27	0.13 821	9.90 777	9	58
3	9.76 974	17	9.86 206	26	0.13 794	9.90 768	9	57
4	9.76 991	18	9.86 232	27	0.13 768	9.90 759	9	56
5	9.77 009	17	9.86 259	26	0.13 741	9.90 750	9	55
6	9.77 026	17	9.86 285	27	0.13 715	9.90 741	10	54
7	9.77 043	18	9.86 312	26	0.13 688	9.90 731	9	53
8	9.77 061	17	9.86 338	27	0.13 662	9.90 722	9	52
9	9.77 078	17	9.86 365	27	0.13 635	9.90 713	9	51
10	9.77 095	17	9.86 392	26	0.13 608	9.90 704	10	50
11	9.77 112	18	9.86 418	27	0.13 582	9.90 694	9	49
12	9.77 130	17	9.86 445	26	0.13 555	9.90 685	9	48
13	9.77 147	17	9.86 471	27	0.13 529	9.90 676	9	47
14	9.77 164	17	9.86 498	26	0.13 502	9.90 667	10	46
15	9.77 181	18	9.86 524	27	0.13 476	9.90 657	9	45
16	9.77 199	17	9.86 551	26	0.13 449	9.90 648	9	44
17	9.77 216	17	9.86 577	26	0.13 423	9.90 639	9	43
18	9.77 233	17	9.86 603	27	0.13 397	9.90 630	10	42
19	9.77 250	18	9.86 630	26	0.13 370	9.90 620	9	41
20	9.77 268	17	9.86 656	27	0.13 344	9.90 611	9	40
21	9.77 285	17	9.86 683	26	0.13 317	9.90 602	10	39
22	9.77 302	17	9.86 709	27	0.13 291	9.90 592	9	38
23	9.77 319	17	9.86 736	26	0.13 264	9.90 583	9	37
24	9.77 336	17	9.86 762	27	0.13 238	9.90 574	9	36
25	9.77 353	17	9.86 789	26	0.13 211	9.90 565	10	35
26	9.77 370	17	9.86 815	27	0.13 185	9.90 555	9	34
27	9.77 387	18	9.86 842	26	0.13 158	9.90 546	9	33
28	9.77 405	17	9.86 868	26	0.13 132	9.90 537	10	32
29	9.77 422	17	9.86 894	27	0.13 106	9.90 527	9	31
30	9.77 439	17	9.86 921	26	0.13 079	9.90 518	9	30
31	9.77 456	17	9.86 947	27	0.13 053	9.90 509	10	28
32	9.77 473	17	9.86 974	26	0.13 026	9.90 499	9	28
33	9.77 490	17	9.87 000	27	0.13 000	9.90 490	10	27
34	9.77 507	17	9.87 027	26	0.12 973	9.90 480	9	26
35	9.77 524	17	9.87 053	26	0.12 947	9.90 471	9	25
36	9.77 541	17	9.87 079	27	0.12 921	9.90 462	10	24
37	9.77 558	17	9.87 106	26	0.12 894	9.90 452	9	23
38	9.77 575	17	9.87 132	26	0.12 868	9.90 443	9	22
39	9.77 592	17	9.87 158	27	0.12 842	9.90 434	10	21
40	9.77 609	17	9.87 185	26	0.12 815	9.90 424	9	20
41	9.77 626	17	9.87 211	27	0.12 789	9.90 415	10	19
42	9.77 643	17	9.87 238	26	0.12 762	9.90 405	9	18
43	9.77 660	17	9.87 264	26	0.12 736	9.90 396	10	17
44	9.77 677	17	9.87 290	27	0.12 710	9.90 386	9	16
45	9.77 694	17	9.87 317	26	0.12 683	9.90 377	9	15
46	9.77 711	17	9.87 343	26	0.12 657	9.90 368	10	14
47	9.77 728	16	9.87 369	27	0.12 631	9.90 358	9	13
48	9.77 744	17	9.87 396	26	0.12 604	9.90 349	10	12
49	9.77 761	17	9.87 422	26	0.12 578	9.90 339	9	11
50	9.77 778	17	9.87 448	27	0.12 552	9.90 330	10	10
51	9.77 795	17	9.87 475	26	0.12 525	9.90 320	9	9
52	9.77 812	17	9.87 501	26	0.12 499	9.90 311	10	8
53	9.77 829	17	9.87 527	27	0.12 473	9.90 301	9	7
54	9.77 846	16	9.87 554	26	0.12 446	9.90 292	10	6
55	9.77 862	17	9.87 580	26	0.12 420	9.90 282	9	5
56	9.77 879	17	9.87 606	27	0.12 394	9.90 273	10	4
57	9.77 896	17	9.87 633	26	0.12 367	9.90 263	9	3
58	9.77 913	17	9.87 659	26	0.12 341	9.90 254	10	2
59	9.77 930	16	9.87 685	26	0.12 315	9.90 244	9	1
60	9.77 948		9.87 711		0.12 289	9.90 235		0
	L SIN	D	L TAN	CD	L COT	L COS	D	323°... 142°...
	L COS		L COT		L TAN	L SIN		233°... 53°...

37°... 217°— 127°... 307°—	L SIN	D	L TAN	CD	L COT	L COS	D		PROP. PTS.
0	9.77 948	17	9.87 711	27	0.12 289	8.90 235	10	60	
1	9.77 963	17	9.87 738	26	0.12 282	8.90 225	9	59	
2	9.77 980	17	9.87 764	26	0.12 236	8.90 216	10	58	
3	9.77 997	16	8.87 790	27	0.12 210	8.80 206	9	57	
4	9.78 013	17	9.87 817	26	0.12 183	8.90 197	10	56	27
5	9.78 030	17	9.87 843	28	0.12 157	8.90 187	8	55	1 2.7
6	9.78 047	16	9.87 869	28	0.12 131	8.90 178	10	54	2 6.4
7	9.78 063	17	9.87 895	27	0.12 105	8.90 168	9	53	3 8.1
8	9.78 080	17	9.87 922	26	0.12 078	8.90 159	10	52	4 10.8
9	9.78 097	16	9.87 948	26	0.12 052	8.90 149	10	51	5 13.6
10	9.78 113	17	9.87 974	26	0.12 026	8.90 139	9	50	6 18.2
11	9.78 130	17	9.88 000	27	0.12 000	8.90 130	10	49	7 18.9
12	9.78 147	16	9.88 027	26	0.11 973	8.90 120	8	48	8 21.8
13	9.78 163	17	9.88 053	26	0.11 947	8.90 111	10	47	9 24.3
14	9.78 180	17	9.88 079	26	0.11 921	8.90 101	10	46	
15	9.78 197	16	9.88 105	26	0.11 895	8.90 091	9	45	28
16	9.78 213	17	9.88 131	27	0.11 869	8.90 082	10	44	1 2.6
17	9.78 230	16	9.88 158	26	0.11 842	8.90 072	9	43	2 5.2
18	9.78 246	17	9.88 184	26	0.11 816	8.90 063	10	42	3 7.8
19	9.78 263	17	9.88 210	26	0.11 790	8.90 053	10	41	4 10.4
20	3.78 280	16	9.88 236	26	0.11 764	8.90 043	9	40	5 13.0
21	9.78 296	17	9.88 262	27	0.11 738	8.90 034	10	39	8 15.6
22	9.78 313	16	9.88 289	26	0.11 711	8.90 024	10	38	7 18.2
23	9.78 329	17	9.88 315	28	0.11 685	8.90 014	9	37	8 20.8
24	9.78 348	16	9.88 341	26	0.11 659	8.90 005	10	36	8 23.4
25	9.78 362	17	9.88 367	28	0.11 633	8.89 995	10	35	
26	9.78 379	16	9.88 393	27	0.11 607	8.89 985	9	34	17
27	9.78 395	17	9.88 420	26	0.11 580	8.89 976	10	33	1 1.7
28	9.78 412	16	9.88 446	26	0.11 554	8.89 966	10	32	2 3.4
29	9.78 428	17	9.88 472	26	0.11 528	8.89 956	9	31	3 5.1
30	9.78 445	16	9.88 498	26	0.11 502	8.89 947	10	30	4 6.8
31	9.78 461	17	9.88 524	26	0.11 476	8.89 937	10	29	5 8.5
32	9.78 478	16	9.88 550	27	0.11 450	8.89 927	9	28	6 10.2
33	9.78 494	16	9.88 577	26	0.11 423	8.89 918	10	27	7 11.9
34	9.78 510	17	9.88 603	26	0.11 397	8.89 908	10	26	8 13.8
35	9.78 527	16	9.88 629	26	0.11 371	8.89 898	10	25	9 15.3
36	9.78 543	17	9.88 655	26	0.11 345	8.89 888	8	24	
37	9.78 560	16	9.88 681	26	0.11 319	8.89 879	10	23	16
38	9.78 576	16	9.88 707	26	0.11 293	8.89 869	10	22	1 1.6
39	9.78 592	17	9.88 733	26	0.11 267	8.89 859	10	21	2 3.2
40	9.78 609	16	9.88 759	27	0.11 241	8.89 849	9	20	3 4.8
41	9.78 625	17	9.88 786	26	0.11 214	8.89 840	10	19	4 6.4
42	9.78 642	16	9.88 812	26	0.11 188	8.89 830	10	18	5 8.0
43	9.78 658	16	9.88 838	26	0.11 162	8.89 820	10	17	6 9.8
44	9.78 674	17	9.88 864	26	0.11 136	8.89 810	9	16	7 11.2
45	9.78 691	16	9.88 890	26	0.11 110	8.89 801	10	15	8 12.8
46	9.78 707	16	9.88 916	26	0.11 084	8.89 791	10	14	9 14.4
47	9.78 723	16	9.88 942	26	0.11 058	8.89 781	10	13	
48	9.78 739	17	9.88 968	26	0.11 032	8.89 771	10	12	
49	9.78 756	16	9.88 994	26	0.11 006	8.89 761	9	11	10 9
50	9.78 772	16	9.89 020	26	0.10 980	8.89 752	10	10	1 1.0
51	9.78 788	17	9.89 046	27	0.10 954	8.89 742	10	9	2 2.0
52	9.78 805	16	9.89 073	26	0.10 927	8.89 732	10	8	3 3.0
53	9.78 821	16	9.89 099	28	0.10 901	8.89 722	10	7	4 4.0
54	9.78 837	16	9.89 125	26	0.10 875	8.89 712	10	6	5 5.0
55	9.78 853	16	9.89 151	26	0.10 849	8.89 702	9	5	6 6.0
56	9.78 869	17	9.89 177	26	0.10 823	8.89 693	10	4	7 7.0
57	9.78 886	16	9.89 203	26	0.10 797	8.89 683	10	3	8 8.0
58	9.78 902	16	9.89 229	26	0.10 771	8.89 673	10	2	9 9.0
59	9.78 918	16	9.89 255	26	0.10 745	8.89 663	10	1	
60	9.78 934		9.89 281		0.10 719	8.89 653		0	
	L SIN	D	L TAN	CD	L COT	L COS	D		322°... 142°—
	L COS		L COT		L TAN	L SIN			232°... 52°—

38°... 218°...	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
128°... 308°...	L COS		L COT		L TAN	L SIN		
0	9.78 934	16	9.89 281	26	0.10 719	9.89 653	10	60
1	9.78 950	17	9.89 307	26	0.10 693	9.89 643	10	59
2	9.78 967	16	9.89 333	26	0.10 667	9.89 633	10	58
3	9.78 983	16	9.89 359	26	0.10 641	9.89 624	10	57
4	9.78 999	16	9.89 385	26	0.10 615	9.89 614	10	56
5	9.79 015	16	9.89 411	26	0.10 589	9.89 604	10	55
6	9.79 031	16	9.89 437	26	0.10 563	9.89 594	10	54
7	9.79 047	16	9.89 463	26	0.10 537	9.89 584	10	53
8	9.79 063	16	9.89 489	26	0.10 511	9.89 574	10	52
9	9.79 079	16	9.89 515	26	0.10 485	9.89 564	10	51
10	9.79 095	16	9.89 541	26	0.10 459	9.89 554	10	50
11	9.79 111	17	9.89 567	26	0.10 433	9.89 544	10	49
12	9.79 128	16	9.89 593	26	0.10 407	9.89 534	10	48
13	9.79 144	16	9.89 619	26	0.10 381	9.89 524	10	47
14	9.79 160	16	9.89 645	26	0.10 355	9.89 514	10	46
15	9.79 176	16	9.89 671	26	0.10 329	9.89 504	9	45
16	9.79 192	16	9.89 697	26	0.10 303	9.89 495	10	44
17	9.79 208	16	9.89 723	26	0.10 277	9.89 485	10	43
18	9.79 224	16	9.89 749	26	0.10 251	9.89 475	10	42
19	9.79 240	16	9.89 775	26	0.10 225	9.89 465	10	41
20	9.79 256	16	9.89 801	26	0.10 199	9.89 455	10	40
21	9.79 272	16	9.89 827	26	0.10 173	9.89 445	10	39
22	9.79 288	16	9.89 853	26	0.10 147	9.89 435	10	38
23	9.79 304	15	9.89 879	26	0.10 121	9.89 425	10	37
24	9.79 319	16	9.89 905	26	0.10 095	9.89 415	10	36
25	9.79 335	16	9.89 931	26	0.10 069	9.89 405	10	35
26	9.79 351	16	9.89 957	26	0.10 043	9.89 395	10	34
27	9.79 367	16	9.89 983	26	0.10 017	9.89 385	10	33
28	9.79 383	16	9.90 009	26	0.09 991	9.89 375	11	32
29	9.79 399	16	9.90 035	26	0.09 965	9.89 364	10	31
30	9.79 415	16	9.90 061	25	0.09 939	9.89 354	10	30
31	9.79 431	16	9.90 086	26	0.09 914	9.89 344	10	29
32	9.79 447	16	9.90 112	26	0.09 888	9.89 334	10	28
33	9.79 463	15	9.90 138	26	0.09 862	9.89 324	10	27
34	9.79 478	16	9.90 164	26	0.09 836	9.89 314	10	26
35	9.79 494	16	9.90 190	26	0.09 810	9.89 304	10	25
36	9.79 510	16	9.90 216	26	0.09 784	9.89 294	10	24
37	9.79 526	16	9.90 242	26	0.09 758	9.89 284	10	23
38	9.79 542	16	9.90 268	26	0.09 732	9.89 274	10	22
39	9.79 558	15	9.90 294	26	0.09 706	9.89 264	10	21
40	9.79 573	16	9.90 320	26	0.09 680	9.89 254	10	20
41	9.79 589	16	9.90 346	25	0.09 654	9.89 244	11	19
42	9.79 605	16	9.90 371	26	0.09 629	9.89 233	10	18
43	9.79 621	15	9.90 397	26	0.09 603	9.89 223	10	17
44	9.79 636	16	9.90 423	26	0.09 577	9.89 213	10	16
45	9.79 652	16	9.90 449	26	0.09 551	9.89 203	10	15
46	9.79 668	16	9.90 475	26	0.09 525	9.89 193	10	14
47	9.79 684	15	9.90 501	26	0.09 499	9.89 183	10	13
48	9.79 699	16	9.90 527	26	0.09 473	9.89 173	11	12
49	9.79 715	16	9.90 553	25	0.09 447	9.89 162	10	11
50	9.79 731	15	9.90 578	26	0.09 422	9.89 152	10	10
51	9.79 746	16	9.90 604	26	0.09 396	9.89 142	10	9
52	9.79 762	16	9.90 630	26	0.09 370	9.89 132	10	8
53	9.79 778	15	9.90 656	26	0.09 344	9.89 122	10	7
54	9.79 793	16	9.90 682	26	0.09 318	9.89 112	11	6
55	9.79 809	16	9.90 708	26	0.09 292	9.89 101	10	5
56	9.79 825	15	9.90 734	25	0.09 266	9.89 091	10	4
57	9.79 840	16	9.90 759	26	0.09 241	9.89 081	10	3
58	9.79 856	16	9.90 785	26	0.09 215	9.89 071	11	2
59	9.79 872	15	9.90 811	26	0.09 189	9.89 060	10	1
60	9.79 887		9.90 837		0.09 163	9.89 050		0
	L SIN	D	L TAN	CD	L COT	L COS	D	321°... 141°...
	L COS		L COT		L TAN	L SIN		231°... 51°...

39°—, 219°— 129°—, 309°—	L SIN	D	L TAN	CD	L COT	L COS	D		PROP. PTS.
	L COS		L COT		L TAN	L SIN			
0	9.79 887	16	9.90 837	26	0.09 163	9.89 050	10	60	
1	9.79 903	15	9.90 863	26	0.09 137	9.89 040	10	59	
2	9.79 918	16	9.90 889	25	0.09 111	9.89 030	10	58	
3	9.79 934	16	9.90 914	26	0.09 086	9.89 020	11	57	26
4	9.79 950	15	9.90 940	26	0.09 060	9.89 009	10	56	1 2.6
5	9.79 965	16	9.90 966	26	0.09 034	9.88 999	10	55	2 5.2
6	9.79 981	15	9.90 992	26	0.09 008	9.88 989	11	54	3 7.8
7	9.79 996	16	9.91 018	25	0.08 982	9.88 978	10	53	4 10.4
8	9.80 012	15	9.91 043	26	0.08 957	9.88 968	10	52	6 13.0
9	9.80 027	16	9.91 069	26	0.08 931	9.88 958	10	51	6 15.6
10	9.80 043	15	9.91 095	26	0.08 905	9.88 948	11	50	7 18.2
11	9.80 058	16	9.91 121	26	0.08 879	9.88 937	10	49	8 20.8
12	9.80 074	15	9.91 147	25	0.08 853	9.88 927	10	48	9 23.4
13	9.80 089	16	9.91 172	26	0.08 828	9.88 917	11	47	
14	9.80 105	15	9.91 198	26	0.08 802	9.88 906	10	46	25
15	9.80 120	16	9.91 224	26	0.08 776	9.88 896	10	45	1 2.5
16	9.80 136	15	9.91 250	26	0.08 750	9.88 886	11	44	2 5.0
17	9.80 151	15	9.91 276	25	0.08 724	9.88 875	10	43	3 7.5
18	9.80 166	16	9.91 301	26	0.08 699	9.88 865	10	42	4 10.8
19	9.80 182	15	9.91 327	26	0.08 673	9.88 855	11	41	5 12.5
20	9.80 197	16	9.91 353	26	0.08 647	9.88 844	10	40	6 15.0
21	9.80 213	15	9.91 379	25	0.08 621	9.88 834	10	39	7 17.5
22	9.80 228	16	9.91 404	26	0.08 596	9.88 824	11	38	8 20.0
23	9.80 244	15	9.91 430	26	0.08 570	9.88 813	10	37	9 22.5
24	9.80 259	15	9.91 456	26	0.08 544	9.88 803	10	36	
25	9.80 274	16	9.91 482	25	0.08 518	9.88 793	11	35	16
26	9.80 290	15	9.91 507	26	0.08 493	9.88 782	10	34	
27	9.80 305	15	9.91 533	26	0.08 467	9.88 772	11	33	1 1.6
28	9.80 320	16	9.91 559	26	0.08 441	9.88 761	10	32	2 3.2
29	9.80 336	15	9.91 585	25	0.08 415	9.88 751	10	31	3 4.8
30	9.80 351	15	9.91 610	26	0.08 390	9.88 741	11	30	4 6.4
31	9.80 366	16	9.91 636	26	0.08 364	9.88 730	10	29	5 8.0
32	9.80 382	15	9.91 662	26	0.08 338	9.88 720	10	28	6 9.6
33	9.80 397	15	9.91 688	25	0.08 312	9.88 709	11	27	7 11.2
34	9.80 412	16	9.91 713	26	0.08 287	9.88 699	10	26	8 12.8
35	9.80 428	15	9.91 739	26	0.08 261	9.88 688	11	25	9 14.4
36	9.80 443	15	9.91 765	26	0.08 235	9.88 678	10	24	
37	9.80 458	15	9.91 791	25	0.08 209	9.88 668	10	23	
38	9.80 473	16	9.91 816	26	0.08 184	9.88 657	11	22	15
39	9.80 489	15	9.91 842	26	0.08 158	9.88 647	10	21	1 1.5
40	9.80 504	15	9.91 868	25	0.08 132	9.88 636	11	20	2 3.0
41	9.80 519	15	9.91 893	26	0.08 107	9.88 626	10	19	3 4.5
42	9.80 534	16	9.91 919	26	0.08 081	9.88 615	11	18	4 6.0
43	9.80 550	15	9.91 945	26	0.08 055	9.88 605	10	17	5 7.5
44	9.80 565	15	9.91 971	25	0.08 029	9.88 594	11	16	6 9.0
45	9.80 580	15	9.91 996	26	0.08 004	9.88 584	10	15	7 10.5
46	9.80 595	15	9.92 022	26	0.07 978	9.88 573	11	14	8 12.0
47	9.80 610	15	9.92 048	25	0.07 952	9.88 563	10	13	9 13.5
48	9.80 625	16	9.92 073	26	0.07 927	9.88 552	11	12	
49	9.80 641	15	9.92 099	26	0.07 901	9.88 542	10	11	11 10'
50	9.80 656	15	9.92 125	25	0.07 875	9.88 531	11	10	1 1.1
51	9.80 671	15	9.92 150	26	0.07 850	9.88 521	10	9	2 2.2
52	9.80 686	15	9.92 176	26	0.07 824	9.88 510	11	8	3 3.3
53	9.80 701	15	9.92 202	25	0.07 798	9.88 499	10	7	4 4.4
54	9.80 716	15	9.92 227	26	0.07 773	9.88 489	11	6	5 5.5
55	9.80 731	15	9.92 253	26	0.07 747	9.88 478	10	5	6 6.6
56	9.80 746	16	9.92 279	25	0.07 721	9.88 468	11	4	7 7.7
57	9.80 762	15	9.92 304	26	0.07 696	9.88 457	10	3	8 8.8
58	9.80 777	15	9.92 330	26	0.07 670	9.88 447	11	2	9 9.9
59	9.80 792	15	9.92 356	25	0.07 644	9.88 436	10	1	
60	9.80 807		9.92 381		0.07 619	9.88 425		0	
	L SIN	D	L TAN	CD	L COT	L COS	D		320°—, 140°— 230°—, 50°—
	L COS		L COT		L TAN	L SIN			

40°—, 220°—	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
130°—, 310°—	L COS		L COT		L TAN	L SIN		
0	9.80 807	15	9.92 381	26	0.07 619	9.88 425	10	60
1	9.80 822	15	9.92 407	26	0.07 593	9.88 415	11	59
2	9.80 837	15	9.92 433	25	0.07 567	9.88 404	10	58
3	9.80 852	15	9.92 458	26	0.07 542	9.88 394	11	57
4	9.80 867	15	9.92 484	26	0.07 516	9.88 383	11	56
5	9.80 882	15	9.92 510	25	0.07 490	9.88 372	10	55
6	9.80 897	15	9.92 535	26	0.07 465	9.88 362	11	54
7	9.80 912	15	9.92 561	26	0.07 439	9.88 351	11	53
8	9.80 927	15	9.92 587	25	0.07 413	9.88 340	10	52
9	9.80 942	15	9.92 612	26	0.07 388	9.88 330	11	51
10	9.80 957	15	9.92 638	25	0.07 362	9.88 319	11	50
11	9.80 972	15	9.92 663	26	0.07 337	9.88 308	10	49
12	9.80 987	15	9.92 689	26	0.07 311	9.88 298	11	48
13	9.81 002	15	9.92 715	25	0.07 285	9.88 287	11	47
14	9.81 017	15	9.92 740	26	0.07 260	9.88 276	10	46
15	9.81 032	15	9.92 766	26	0.07 234	9.88 266	11	45
16	9.81 047	14	9.92 792	25	0.07 208	9.88 255	11	44
17	9.81 061	15	9.92 817	26	0.07 183	9.88 244	10	43
18	9.81 076	15	9.92 843	25	0.07 157	9.88 234	11	42
19	9.81 091	15	9.92 868	26	0.07 132	9.88 223	11	41
20	9.81 106	15	9.92 894	26	0.07 106	9.88 212	11	40
21	9.81 121	15	9.92 920	25	0.07 080	9.88 201	10	39
22	9.81 136	15	9.92 945	26	0.07 055	9.88 191	11	38
23	9.81 151	15	9.92 971	25	0.07 029	9.88 180	11	37
24	9.81 166	14	9.92 996	26	0.07 004	9.88 169	11	36
25	9.81 180	15	9.93 022	26	0.06 978	9.88 158	10	35
26	9.81 195	15	9.93 048	25	0.06 952	9.88 148	11	34
27	9.81 210	15	9.93 073	26	0.06 927	9.88 137	11	33
28	9.81 225	15	9.93 099	25	0.06 901	9.88 126	11	32
29	9.81 240	14	9.93 124	26	0.06 876	9.88 115	10	31
30	9.81 254	15	9.93 150	25	0.06 850	9.88 105	11	30
31	9.81 269	15	9.93 175	26	0.06 825	9.88 094	11	29
32	9.81 284	15	9.93 201	26	0.06 799	9.88 083	11	28
33	9.81 299	15	9.93 227	25	0.06 773	9.88 072	11	27
34	9.81 314	14	9.93 252	26	0.06 748	9.88 061	10	26
35	9.81 328	15	9.93 278	25	0.06 722	9.88 051	11	25
36	9.81 343	15	9.93 303	26	0.06 697	9.88 040	11	24
37	9.81 358	14	9.93 329	25	0.06 671	9.88 029	11	23
38	9.81 372	15	9.93 354	26	0.06 646	9.88 018	11	22
39	9.81 387	15	9.93 380	26	0.06 620	9.88 007	11	21
40	9.81 402	15	9.93 406	25	0.06 594	9.87 996	11	20
41	9.81 417	14	9.93 431	26	0.06 569	9.87 985	10	19
42	9.81 431	15	9.93 457	25	0.06 543	9.87 975	11	18
43	9.81 446	15	9.93 482	26	0.06 518	9.87 964	11	17
44	9.81 461	14	9.93 508	25	0.06 492	9.87 953	11	16
45	9.81 475	15	9.93 533	26	0.06 467	9.87 942	11	15
46	9.81 490	15	9.93 559	25	0.06 441	9.87 931	11	14
47	9.81 505	14	9.93 584	26	0.06 416	9.87 920	11	13
48	9.81 519	15	9.93 610	26	0.06 390	9.87 909	11	12
49	9.81 534	15	9.93 636	25	0.06 364	9.87 898	11	11
50	9.81 549	14	9.93 661	26	0.06 339	9.87 887	10	10
51	9.81 563	15	9.93 687	25	0.06 313	9.87 877	11	9
52	9.81 578	14	9.93 712	26	0.06 288	9.87 866	11	8
53	9.81 592	15	9.93 738	25	0.06 262	9.87 855	11	7
54	9.81 607	15	9.93 763	26	0.06 237	9.87 844	11	6
55	9.81 622	14	9.93 789	25	0.06 211	9.87 833	11	5
56	9.81 636	15	9.93 814	26	0.06 186	9.87 822	11	4
57	9.81 651	14	9.93 840	25	0.06 160	9.87 811	11	3
58	9.81 665	15	9.93 865	26	0.06 135	9.87 800	11	2
59	9.81 680	14	9.93 891	25	0.06 109	9.87 789	11	1
60	9.81 694		9.93 916		0.06 084	9.87 778		0
	L SIN	D	L TAN	CD	L COT	L COS	D	319°—, 139°—
	L COS		L COT		L TAN	L SIN		229°—, 49°—

41°—, 221°—		L SIN		L TAN		L COT	L COS			PROP. PTS.
131°—, 311°—		L COS	D	L COT	CD	L TAN	L SIN	D		
	0	9.81 694	15	9.93 916	26	0.06 084	8.87 778	11	60	
	1	9.81 709	14	9.93 942	26	0.06 068	8.87 787	11	59	
	2	9.81 723	15	9.93 967	28	0.06 033	8.87 766	11	58	26
	3	9.81 738	14	9.93 993	25	0.06 007	8.87 746	11	57	1 2.6
	4	9.81 752	16	9.94 018	26	0.05 982	8.87 734	11	56	2 5.2
	6	9.81 767	14	9.94 044	25	0.05 958	8.87 723	11	55	3 7.8
	8	9.81 781	15	9.94 069	28	0.05 931	8.87 712	11	54	4 10.4
	7	9.81 796	14	9.94 096	25	0.05 905	8.87 701	11	53	5 13.0
	8	9.81 810	16	9.94 120	28	0.05 880	8.87 690	11	52	8 15.8
	9	9.81 825	14	9.94 148	25	0.05 854	8.87 679	11	51	7 18.2
	10	9.81 839	15	9.94 171	26	0.05 829	8.87 668	11	50	8 20.8
	11	9.81 854	14	9.94 197	25	0.05 803	8.87 657	11	49	9 23.4
	12	9.81 868	14	9.94 222	26	0.05 778	8.87 646	11	48	
	13	9.81 882	15	9.94 248	25	0.05 762	8.87 635	11	47	25
	14	9.81 897	14	9.94 273	26	0.05 727	8.87 624	11	46	.1 2.5
	16	9.81 911	15	9.94 299	25	0.05 701	8.87 613	12	45	2 5.0
	18	9.81 926	14	9.94 324	26	0.05 676	8.87 601	11	44	3 7.6
	17	9.81 940	15	9.94 350	25	0.05 650	8.87 590	11	43	4 10.0
	18	9.81 955	14	9.94 375	26	0.05 625	8.87 579	11	42	5 12.5
	19	9.81 989	14	9.94 401	25	0.06 599	8.87 568	11	41	6 15.0
	20	9.81 983	15	9.94 426	26	0.05 574	8.87 557	11	40	7 17.5
	21	9.81 998	14	9.94 452	25	0.05 548	8.87 546	11	39	8 20.0
	22	9.82 012	14	9.94 477	28	0.05 623	8.87 535	11	38	9 22.5
	23	9.82 028	15	9.94 503	25	0.05 497	8.87 524	11	37	
	24	9.82 041	14	9.94 528	26	0.05 472	8.87 513	12	38	
	25	9.82 055	14	9.94 554	25	0.05 446	8.87 501	11	35	15
	28	9.82 069	15	9.94 579	25	0.05 421	8.87 490	11	34	
	27	9.82 084	14	9.94 604	28	0.05 396	8.87 479	11	33	1 1.5
	28	9.82 098	14	9.94 630	25	0.05 370	8.87 468	11	32	2 3.0
	29	9.82 112	14	9.94 655	26	0.05 345	8.87 457	11	31	3 4.5
	30	9.82 126	15	9.94 681	25	0.05 319	8.87 448	12	30	4 8.0
	31	9.82 141	14	9.94 706	26	0.05 294	8.87 434	11	29	5 7.5
	32	9.82 155	14	9.94 732	25	0.05 268	8.87 423	11	28	6 9.0
	33	9.82 169	15	9.94 757	26	0.05 243	8.87 412	11	27	7 10.5
	34	9.82 184	14	9.94 783	25	0.05 217	8.87 401	11	28	8 12.0
	35	9.82 198	14	9.94 808	26	0.05 192	8.87 390	12	25	8 13.5
	36	9.82 212	14	9.94 834	25	0.05 166	8.87 378	11	24	
	37	9.82 226	14	9.94 859	25	0.05 141	8.87 367	11	23	14
	38	9.82 240	15	9.94 884	26	0.05 116	8.87 356	11	22	1 1.4
	39	9.82 255	14	9.94 910	25	0.05 090	8.87 345	11	21	2 2.8
	40	9.82 269	14	9.94 935	26	0.05 065	8.87 324	12	20	3 4.2
	41	9.82 283	14	9.94 961	25	0.05 039	8.87 322	11	19	4 5.6
	42	9.82 297	14	9.94 986	26	0.05 014	8.87 311	11	18	5 7.0
	43	9.82 311	15	9.95 012	25	0.04 988	8.87 300	12	17	6 8.4
	44	9.82 326	14	9.95 037	25	0.04 963	8.87 288	11	16	7 9.8
	45	9.82 340	14	9.95 062	26	0.04 938	8.87 277	11	15	8 11.2
	46	9.82 354	14	9.95 088	25	0.04 912	8.87 266	11	14	9 12.6
	47	9.82 368	14	9.95 113	28	0.04 887	8.87 256	12	13	
	48	9.82 382	14	9.95 139	25	0.04 861	8.87 243	11	12	
	49	9.82 396	14	9.95 164	26	0.04 838	8.87 232	11	11	
	50	9.82 410	14	9.95 190	25	0.04 810	8.87 221	12	10	1 1.2
	51	9.82 424	15	9.95 215	25	0.04 785	8.87 209	11	9	2 2.4
	52	9.82 439	14	9.95 240	26	0.04 760	8.87 198	11	8	3 3.6
	53	9.82 453	14	9.95 266	25	0.04 734	8.87 187	12	7	4 4.8
	54	9.82 467	14	9.95 291	26	0.04 709	8.87 175	11	6	5 6.0
	55	9.82 481	14	9.95 317	25	0.04 683	8.87 164	11	5	6 7.2
	56	9.82 495	14	9.95 342	26	0.04 658	8.87 153	12	4	7 8.4
	57	9.82 509	14	9.95 368	25	0.04 632	8.87 141	11	3	8 9.6
	58	9.82 523	14	9.95 393	25	0.04 607	8.87 130	11	2	9 10.8
	59	9.82 537	14	9.95 418	26	0.04 582	8.87 119	12	1	9.9
	60	9.82 551		9.95 444		0.04 558	8.87 107		0	
		L SIN	D	L TAN	CD	L COT	L COS	D		318°—, 138°—
		L COS		L COT		L TAN	L SIN			228°—, 48°—

42° ... 222°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
132° ... 312°	L COS		L COT		L TAN	L SIN		
0	9.82 551	14	9.95 444	25	0.04 556	9.87 107	11	60
1	9.82 565	14	9.95 469	26	0.04 531	9.87 086	11	59
2	9.82 579	14	9.95 495	25	0.04 505	9.87 085	12	58
3	9.82 593	14	8.95 520	25	0.04 480	9.87 073	11	57
4	9.82 607	14	8.95 545	26	0.04 455	9.87 062	12	56
5	9.82 621	14	9.95 571	25	0.04 429	9.87 050	11	55
6	9.82 635	14	9.95 596	28	0.04 404	9.87 039	11	54
7	9.82 649	14	8.95 622	25	0.04 378	9.87 028	12	53
8	9.82 663	14	8.95 647	25	0.04 353	9.87 016	12	52
9	9.82 677	14	8.95 672	26	0.04 328	9.87 005	11	51
10	9.82 691	14	9.95 698	25	0.04 302	9.86 993	11	50
11	9.82 705	14	9.95 723	25	0.04 277	9.86 982	12	49
12	9.82 719	14	9.95 748	26	0.04 252	9.86 970	11	48
13	9.82 733	14	9.95 774	25	0.04 226	9.86 959	12	47
14	9.82 747	14	9.95 799	26	0.04 201	9.86 947	11	46
15	8.82 761	14	9.95 825	25	0.04 175	9.86 936	12	45
16	9.82 775	13	9.95 820	25	0.04 150	9.86 924	11	44
17	9.82 788	14	9.95 875	26	0.04 125	9.86 913	11	43
18	9.82 802	14	9.95 901	25	0.04 098	9.86 902	12	42
19	9.82 816	14	9.95 926	26	0.04 074	9.86 890	11	41
20	9.82 830	14	9.95 952	25	0.04 048	9.86 879	12	40
21	9.82 844	14	9.95 977	25	0.04 023	9.86 867	12	39
22	9.82 858	14	9.96 002	26	0.03 998	9.86 855	11	38
23	9.82 872	13	9.96 028	25	0.03 972	9.86 844	12	37
24	9.82 885	14	9.96 053	25	0.03 947	9.86 832	11	36
25	9.82 899	14	9.96 078	26	0.03 922	9.86 821	12	35
26	9.82 913	14	9.96 104	25	0.03 896	9.86 809	11	34
27	9.82 927	14	9.96 129	26	0.03 871	9.86 798	12	33
28	9.82 941	14	9.96 155	25	0.03 845	9.86 786	11	32
29	9.82 955	13	9.96 180	25	0.03 820	9.86 775	12	31
30	9.82 968	14	9.95 205	28	0.03 795	9.86 763	11	30
31	9.82 982	14	9.96 231	25	0.03 769	9.86 752	12	29
32	9.82 996	14	9.96 256	25	0.03 744	9.86 740	12	28
33	9.83 010	13	9.96 281	26	0.03 719	9.86 728	11	27
34	8.83 023	14	9.96 307	25	0.03 693	9.86 717	12	26
35	9.83 037	14	9.88 332	25	0.03 668	9.86 705	11	25
36	9.83 051	14	9.96 357	26	0.03 643	9.86 694	12	24
37	9.83 065	14	9.96 383	25	0.03 617	9.86 682	12	23
38	9.83 078	13	9.96 408	25	0.03 592	9.86 670	11	22
39	9.83 092	14	9.96 433	26	0.03 567	9.86 659	12	21
40	9.83 106	14	9.98 459	25	0.03 541	9.86 647	12	20
41	9.83 120	13	9.96 484	26	0.03 516	9.86 635	11	19
42	9.83 133	14	9.96 510	25	0.03 490	9.86 624	12	18
43	9.83 147	14	9.96 535	25	0.03 465	9.86 612	12	17
44	9.83 161	13	9.98 560	26	0.03 440	9.86 600	11	16
45	9.83 174	14	9.96 586	25	0.03 414	9.86 589	12	15
46	9.83 188	14	9.96 611	25	0.03 389	9.86 577	12	14
47	9.83 202	13	9.96 636	28	0.03 364	9.86 565	11	13
48	9.83 215	14	9.98 662	25	0.03 338	9.86 554	12	12
49	9.83 229	13	9.96 687	25	0.03 313	9.86 542	12	11
50	9.83 242	14	9.96 712	26	0.03 288	9.86 530	12	10
51	9.83 256	14	9.86 738	25	0.03 262	9.86 518	11	9
52	9.83 270	13	9.96 763	25	0.03 237	9.86 507	12	8
53	9.83 283	14	9.96 788	26	0.03 212	9.86 495	12	7
54	9.83 297	13	9.96 814	25	0.03 186	9.86 483	11	6
55	9.83 310	14	9.96 839	25	0.03 161	9.86 472	12	5
56	9.83 324	14	8.96 864	26	0.03 136	9.86 460	12	4
57	9.83 338	13	9.96 890	25	0.03 110	9.86 448	12	3
58	9.83 351	14	9.96 915	25	0.03 085	9.86 436	11	2
59	9.83 365	13	8.96 940	26	0.03 060	9.86 425	12	1
60	9.83 378		9.96 966		0.03 034	9.86 413		0
	L SIN	D	L TAN	CD	L COT	L COS	D	317° ... 137°
	L COS		L COT		L TAN	L SIN		227° ... 47°

43°... 223°	L SIN	D	L TAN	CD	L COT	L COS	D	PROP. PTS.
133°... 313°	L COS		L COT		L TAN	L SIN		
0	9.83 376	14	9.96 966	25	0.03 034	9.86 413	12	60
1	9.83 392	13	9.96 981	25	0.03 009	9.86 401	12	59
2	9.83 406	14	9.97 018	26	0.02 984	9.86 389	12	58
3	9.83 419	13	9.97 042	25	0.02 958	9.86 377	11	57
4	9.83 432	14	9.97 067	25	0.02 933	9.86 366	12	58
5	9.83 446	13	9.97 092	28	0.02 908	9.86 354	12	55
6	9.83 459	14	9.97 116	25	0.02 882	9.86 342	12	54
7	9.83 473	13	9.97 143	25	0.02 857	9.86 330	12	53
8	9.83 486	14	9.97 166	25	0.02 832	9.86 318	12	52
9	9.93 500	13	9.97 193	26	0.02 807	9.86 306	11	51
10	9.83 513	14	9.97 219	25	0.02 781	9.86 295	12	50
11	9.83 527	13	9.97 244	25	0.02 756	9.86 283	12	49
12	9.83 540	14	9.97 269	25	0.02 731	9.86 271	12	48
13	9.83 554	13	9.97 295	25	0.02 705	9.86 259	12	47
14	9.83 567	14	9.96 320	25	0.02 680	9.86 247	12	46
15	9.83 581	13	9.97 345	26	0.02 655	9.86 235	12	45
16	9.83 594	14	9.97 371	25	0.02 620	9.86 223	12	44
17	9.83 608	13	9.97 398	25	0.02 601	9.86 211	11	43
18	9.83 621	13	9.97 421	25	0.02 579	9.86 200	12	42
19	9.83 634	14	9.97 447	25	0.02 553	9.86 188	12	41
20	9.83 648	13	9.97 472	25	0.02 528	9.86 178	12	40
21	9.83 661	13	9.97 497	26	0.02 503	9.86 184	12	39
22	9.83 674	14	9.97 523	25	0.02 477	9.86 152	12	38
23	9.83 688	13	9.97 518	25	0.02 452	9.86 140	12	37
24	9.83 701	14	9.97 573	25	0.02 427	9.86 128	12	36
25	9.83 715	13	9.97 598	28	0.02 402	9.86 115	12	35
26	9.83 728	13	9.97 624	25	0.02 376	9.86 104	12	34
27	9.83 741	14	9.97 649	25	0.02 351	9.86 092	12	33
28	9.83 755	13	9.97 674	26	0.02 328	9.86 080	12	32
29	9.83 768	13	9.97 700	25	0.02 300	9.86 068	12	31
30	9.83 781	14	9.97 725	25	0.02 275	9.86 055	12	30
31	9.83 795	13	9.97 750	26	0.02 250	9.86 044	12	29
32	9.83 808	13	9.97 778	25	0.02 224	9.86 032	12	28
33	9.83 821	13	9.97 801	25	0.02 190	9.86 020	12	27
34	9.83 834	14	9.97 828	25	0.02 174	9.86 008	12	26
35	9.83 848	13	9.97 851	25	0.02 149	9.85 998	12	25
36	9.83 861	13	9.97 877	25	0.02 123	9.85 984	12	24
37	9.83 874	13	9.97 902	25	0.02 098	9.85 972	12	23
38	9.83 887	14	9.97 927	26	0.02 073	9.85 960	12	22
39	9.83 901	13	9.97 953	25	0.02 047	9.85 948	12	21
40	9.83 914	13	9.97 978	25	0.02 022	9.85 935	12	20
41	9.83 927	13	9.98 003	28	0.01 997	9.85 924	12	19
42	9.83 940	14	9.98 029	25	0.01 971	9.85 912	12	18
43	9.83 954	13	9.98 054	25	0.01 948	9.85 900	12	17
44	9.83 967	13	9.98 079	25	0.01 921	9.85 888	12	16
45	9.83 980	13	9.98 104	28	0.01 895	9.85 875	12	15
46	9.83 993	13	9.98 130	25	0.01 870	9.85 864	13	14
47	9.84 006	14	9.98 155	25	0.01 845	9.85 851	12	13
48	9.84 020	13	9.98 180	26	0.01 820	9.85 839	12	12
49	9.84 033	13	9.98 208	25	0.01 794	9.85 827	12	11
50	9.84 048	13	9.98 231	25	0.01 789	9.85 815	12	10
51	9.84 059	13	9.98 255	25	0.01 744	9.85 803	12	9
52	9.84 072	13	9.98 281	25	0.01 719	9.85 791	12	8
53	9.83 085	13	9.98 307	25	0.01 693	9.85 779	13	7
54	9.84 098	14	9.98 332	25	0.01 668	9.85 766	12	6
55	9.84 112	13	9.98 357	26	0.01 643	9.85 754	12	5
56	9.84 125	13	9.98 383	25	0.01 617	9.85 742	12	4
57	9.84 138	13	9.98 408	25	0.01 592	9.85 730	12	3
58	9.84 151	13	9.98 433	25	0.01 567	9.85 718	12	2
59	9.84 164	13	9.98 458	28	0.01 542	9.85 706	13	1
60	9.84 177		9.98 484		0.01 515	9.85 693		0
	L SIN	D	L TAN	CD	L COT	L COS	D	316°... 136°
	L COS		L COT		L TAN	L SIN		226°... 46°

44°—, 224°—		L SIN	D	L TAN	CD	L COT	L COS	D		PROP. PTS.
134°—, 314°—		L COS		L COT		L TAN	L SIN			
	0	9.84 177	13	9.98 484	25	0.01 516	9.85 693	12	60	1 2.6 2 5.2 3 7.8 4 10.4 5 13.0 6 15.6 7 18.2 8 20.8 9 23.4 25 1 2.5 2 5.0 3 7.5 4 10.0 5 12.5 6 15.0 7 17.5 8 20.0 9 22.5 14 1 1.4 2 2.8 3 4.2 4 5.6 5 7.0 6 8.4 7 9.8 8 11.2 9 12.6 13 1 1.3 2 2.6 3 3.9 4 5.2 5 6.5 6 7.8 7 9.1 8 10.4 9 11.7 12 1 1.2 2 2.4 3 3.6 4 4.9 5 6.0 6 7.2 7 9.4 8 9.6 9 10.8
	1	9.84 190	13	9.98 509	25	0.01 491	9.85 681	12	59	
	2	9.84 203	13	9.98 534	26	0.01 466	9.85 669	12	58	
	3	9.84 215	13	9.98 560	25	0.01 440	9.85 657	12	57	
	4	9.84 229	13	9.98 585	25	0.01 415	9.85 645	12	56	
	5	9.84 242	13	9.98 610	25	0.01 390	9.85 632	12	55	
	6	9.84 255	14	9.98 635	26	0.01 365	9.85 620	12	54	
	7	9.84 269	13	9.98 661	25	0.01 339	9.85 609	12	53	
	8	9.84 282	13	9.98 686	25	0.01 314	9.85 596	12	52	
	9	9.84 295	13	9.98 711	26	0.01 289	9.85 583	12	51	
	10	9.84 308	13	9.98 737	25	0.01 263	9.85 571	12	50	
	11	9.84 321	13	9.98 762	25	0.01 238	9.85 559	12	49	
	12	9.84 334	13	9.98 787	25	0.01 213	9.85 547	12	48	
	13	9.84 347	13	9.98 812	26	0.01 188	9.85 534	12	47	
	14	9.84 360	13	9.98 838	25	0.01 162	9.85 522	12	46	
	15	9.84 373	12	9.98 863	25	0.01 137	9.85 510	13	45	
	16	9.84 385	13	9.98 888	25	0.01 112	9.85 497	12	44	
	17	9.84 398	13	9.98 913	26	0.01 087	9.85 485	12	43	
	18	9.84 411	13	9.98 939	25	0.01 061	9.85 473	12	42	
	19	9.84 424	13	9.98 964	25	0.01 036	9.85 460	12	41	
	20	9.84 437	13	9.98 989	26	0.01 011	9.85 448	12	40	
	21	9.84 450	13	9.99 015	25	0.00 985	9.85 436	12	39	
	22	9.84 463	13	9.99 040	25	0.00 960	9.85 423	12	38	
	23	9.8 76	13	9.99 065	25	0.00 935	9.85 411	12	37	
	24	9.84 489	13	9.99 090	26	0.00 910	9.85 399	12	36	
	25	9.84 502	13	9.99 116	25	0.00 884	9.85 386	12	35	
	26	9.84 515	13	9.99 141	25	0.00 859	9.85 374	12	34	
	27	9.84 528	12	9.99 166	25	0.00 834	9.85 361	12	33	
	28	9.84 540	13	9.99 191	26	0.00 809	9.85 349	12	32	
	29	9.84 553	13	9.99 217	25	0.00 783	9.85 337	12	31	
	30	9.84 565	13	9.99 242	25	0.00 758	9.85 324	12	30	
	31	9.84 579	13	9.99 267	26	0.00 733	9.85 312	12	29	
	32	9.84 592	13	9.99 293	25	0.00 707	9.85 299	12	28	
	33	9.84 605	13	9.99 318	25	0.00 682	9.85 287	12	27	
	34	9.84 618	12	9.99 343	26	0.00 657	9.85 274	12	26	
	35	9.84 630	13	9.99 368	25	0.00 632	9.85 262	12	25	
	36	9.84 643	13	9.99 394	25	0.00 606	9.85 250	12	24	
	37	9.84 656	13	9.99 419	25	0.00 581	9.85 237	12	23	
	38	9.84 669	13	9.99 444	25	0.00 556	9.85 225	12	22	
	39	9.84 682	12	9.99 469	25	0.00 531	9.85 212	12	21	
	40	9.84 694	13	9.99 495	25	0.00 505	9.85 200	12	20	
	41	9.84 707	13	9.99 520	25	0.00 480	9.85 187	12	19	
	42	9.84 720	13	9.99 545	25	0.00 455	9.85 175	12	18	
	43	9.84 733	12	9.99 570	25	0.00 430	9.85 162	12	17	
	44	9.84 745	13	9.99 596	25	0.00 404	9.85 150	12	16	
	45	9.84 758	13	9.99 621	25	0.00 379	9.85 137	12	15	
	46	9.84 771	13	9.99 646	26	0.00 354	9.85 125	12	14	
	47	9.84 784	12	9.99 672	25	0.00 328	9.85 112	12	13	
	48	9.84 796	13	9.99 697	25	0.00 303	9.85 100	12	12	
	49	9.84 809	13	9.99 722	25	0.00 278	9.85 087	12	11	
	50	9.84 822	13	9.99 747	26	0.00 253	9.85 074	12	10	
	51	9.84 835	12	9.99 773	25	0.00 227	9.85 062	12	9	
	52	9.84 847	13	9.99 799	25	0.00 202	9.85 049	12	8	
	53	9.84 860	13	9.99 823	25	0.00 177	9.85 037	12	7	
	54	9.84 873	12	9.99 848	26	0.00 152	9.85 024	12	6	
	55	9.84 885	13	9.99 974	25	0.00 126	9.85 012	12	5	
	56	9.84 898	13	9.99 899	25	0.00 101	9.84 999	12	4	
	57	9.84 911	12	9.99 924	25	0.00 076	9.84 986	12	3	
	58	9.84 923	13	9.99 849	25	0.00 051	9.84 974	12	2	
	59	9.84 936	13	9.99 975	25	0.00 025	9.84 961	12	1	
60	9.84 949		0.00 000		0.00 000	9.84 849		0		
	L SIN	D	L TAN	CD	L COT	L COS	D		315°—, 135°—	
	L COS		L COT		L TAN	L SIN			225°—, 45°—	

Appendix C

DEAD RECKONING ALTITUDE AND AZIMUTH TABLE

WHEN LHA (E OR) W IS GREATER THAN 90°. TAKE "K" FROM BOTTOM OF TABLE

	0°00'		0°30'		1°00'		1°30'		2°00'		
	A	B	A	B	A	B	A	B	A	B	
0	 0.0		205916 1.7		175814 6.6		158208 14.9		145718 26.5		30
	383730 0.0		205198 1.7		175454 6.7		157967 15.1		145538 26.7		
1	353627 0.0		204492 1.8		175097 6.8		157728 15.2		145358 26.9		29
	336018 0.0		203797 1.8		174742 7.0		157490 15.4		145179 27.1		
2	323524 0.0		203113 1.9		174391 7.1		157254 15.6		145000 27.3		28
	313833 0.0		202440 1.9		174042 7.2		157019 15.7		144823 27.6		
3	305915 0.0		201777 2.0		173696 7.3		156784 15.9		144646 27.8		27
	299221 0.0		201124 2.1		173352 7.4		156552 16.1		144470 28.0		
4	293421 0.0		200480 2.1		173012 7.5		156320 16.2		144295 28.3		26
	288306 0.0		199846 2.2		172674 7.6		156090 16.4		144120 28.5		
5	283730 0.0		199221 2.3		172339 7.8		155861 16.6		143946 28.7		25
	279591 0.1		198605 2.3		172006 7.9		155633 16.8		143773 28.9		
6	275812 0.1		197998 2.4		171676 8.0		155406 16.9		143600 29.2		24
	272336 0.1		197399 2.4		171348 8.1		155180 17.1		143428 29.4		
7	269118 0.1		196808 2.5		171023 8.2		154956 17.3		143257 29.6		23
	266121 0.1		196225 2.6		170700 8.4		154733 17.5		143086 29.9		
8	263318 0.1		195650 2.7		170379 8.5		154511 17.6		142916 30.1		22
	260685 0.1		195082 2.7		170061 8.6		154290 17.8		142747 30.4		
9	258203 0.1		194522 2.8		169745 8.7		154070 18.0		142579 30.6		21
	255855 0.2		193969 2.9		169432 8.9		153851 18.2		142411 30.8		
10	253627 0.2		193422 2.9		169121 9.0		153633 18.4		142243 31.1		20
	251508 0.2		192883 3.0		168811 9.1		153417 18.6		142077 31.3		
11	249488 0.2		192350 3.1		168505 9.3		153201 18.7		141911 31.5		19
	247558 0.2		191824 3.2		168200 9.4		152987 18.9		141745 31.8		
12	245709 0.3		191303 3.2		167897 9.5		152774 19.1		141581 32.0		18
	243936 0.3		190790 3.3		167597 9.7		152561 19.3		141417 32.3		
13	242233 0.3		190282 3.4		167298 9.8		152350 19.5		141253 32.5		17
	240594 0.3		189780 3.5		167002 9.9		152140 19.7		141090 32.8		
14	239015 0.4		189283 3.6		166708 10.1		151931 19.9		140928 33.0		16
	237491 0.4		188793 3.6		166415 10.2		151722 20.1		140766 33.3		
15	236018 0.4		188307 3.7		166125 10.3		151515 20.3		140605 33.5		15
	234594 0.4		187827 3.8		165836 10.5		151309 20.5		140445 33.7		
16	233215 0.5		187353 3.9		165550 10.6		151104 20.6		140285 34.0		14
	231879 0.5		186883 4.0		165265 10.8		150899 20.8		140125 34.2		
17	230583 0.5		186419 4.1		164982 10.9		150696 21.0		139967 34.5		13
	229324 0.6		185959 4.1		164701 11.0		150494 21.2		139809 34.7		
18	228100 0.6		185505 4.2		164422 11.2		150292 21.4		139651 35.0		12
	226910 0.6		185055 4.3		164144 11.3		150092 21.6		139494 35.3		
19	225752 0.7		184609 4.4		163868 11.5		149892 21.8		139338 35.5		11
	224624 0.7		184168 4.5		163594 11.6		149693 22.0		139182 35.8		
20	223525 0.7		183732 4.6		163322 11.8		149495 22.2		139027 36.0		10
	222452 0.8		183300 4.7		163052 11.9		149299 22.4		138872 36.3		
21	221406 0.8		182872 4.8		162783 12.1		149103 22.6		138718 36.5		9
	220384 0.9		182448 4.9		162516 12.2		148907 22.9		138564 36.8		
22	219385 0.9		182029 5.0		162250 12.4		148713 23.1		138411 37.1		8
	218409 0.9		181613 5.1		161986 12.5		148520 23.3		138258 37.3		
23	217455 1.0		181201 5.2		161724 12.7		148327 23.5		138106 37.6		7
	216521 1.0		180794 5.3		161463 12.8		148135 23.7		137955 37.9		
24	215607 1.1		180390 5.4		161204 13.0		147945 23.9		137804 38.1		6
	214711 1.1		179990 5.5		160946 13.1		147755 24.1		137653 38.4		
25	213834 1.1		179593 5.6		160690 13.3		147566 24.3		137504 38.6		5
	212974 1.2		179200 5.7		160435 13.4		147377 24.5		137354 38.9		
26	212130 1.2		178810 5.8		160182 13.6		147190 24.7		137205 39.2		4
	211303 1.3		178424 5.9		159930 13.8		147003 24.9		137057 39.4		
27	210491 1.3		178042 6.0		159680 13.9		146817 25.2		136909 39.7		3
	209695 1.4		177663 6.1		159431 14.1		146632 25.4		136761 40.0		
28	208912 1.4		177287 6.2		159184 14.2		146448 25.6		136615 40.3		2
	208143 1.5		176914 6.3		158938 14.4		146264 25.8		136468 40.5		
29	207388 1.5		176544 6.4		158693 14.6		146081 26.0		136322 40.8		1
	206646 1.6		176178 6.5		158450 14.7		145899 26.2		136177 41.1		
30	205916 1.7		175814 6.6		158208 14.9		145718 26.5		136032 41.4		0
	A	B	A	B	A	B	A	B	A	B	
	179°30'		179°00'		178°30'		178°00'		177°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	2°30'		3°00'		3°30'		4°00'		4°30'		
	A	B	A	B	A	B	A	B	A	B	
0	136032 ... 41.4		128120 ... 59.6		121432 ... 81.1		115641 ... 105.9		110536 ... 134.1		30
	135888 ... 41.6		128000 ... 59.9		121329 ... 81.5		115551 ... 106.4		110455 ... 134.6		
1	135744 ... 41.9		127880 ... 60.2		121226 ... 81.9		115461 ... 106.8		110375 ... 135.1		29
	135600 ... 42.2		127760 ... 60.6		121124 ... 82.2		115371 ... 107.3		110296 ... 135.6		
2	135457 ... 42.5		127640 ... 60.9		121021 ... 82.6		115282 ... 107.7		110218 ... 136.1		28
	135315 ... 42.7		127521 ... 61.2		120919 ... 83.0		115192 ... 108.1		110136 ... 136.6		
3	135173 ... 43.0		127403 ... 61.6		120817 ... 83.4		115103 ... 108.6		110057 ... 137.1		27
	135031 ... 43.3		127284 ... 61.9		120715 ... 83.8		115014 ... 109.0		109977 ... 137.6		
4	134890 ... 43.6		127166 ... 62.2		120614 ... 84.2		114925 ... 109.5		109898 ... 138.1		26
	134749 ... 43.9		127049 ... 62.6		120513 ... 84.6		114836 ... 109.9		109819 ... 138.6		
5	134609 ... 44.2		126931 ... 62.9		120412 ... 85.0		114747 ... 110.4		109740 ... 139.1		25
	134469 ... 44.4		126814 ... 63.3		120311 ... 85.4		114659 ... 110.8		109662 ... 139.6		
6	134330 ... 44.7		126697 ... 63.6		120211 ... 85.8		114571 ... 111.3		109583 ... 140.1		24
	134191 ... 45.0		126581 ... 63.9		120110 ... 86.2		114483 ... 111.7		109505 ... 140.6		
7	134052 ... 45.3		126465 ... 64.3		120010 ... 86.6		114395 ... 112.2		109426 ... 141.1		23
	133914 ... 45.6		126349 ... 64.6		119910 ... 87.0		114307 ... 112.7		109348 ... 141.7		
8	133777 ... 45.9		126233 ... 65.0		119811 ... 87.4		114220 ... 113.1		109270 ... 142.2		22
	133640 ... 46.2		126118 ... 65.3		119711 ... 87.8		114133 ... 113.6		109192 ... 142.7		
9	133503 ... 46.5		126003 ... 65.7		119612 ... 88.2		114045 ... 114.0		109115 ... 143.2		21
	133367 ... 46.8		125888 ... 66.0		119513 ... 88.6		113958 ... 114.5		109037 ... 143.7		
10	133231 ... 47.1		125774 ... 66.4		119415 ... 89.0		113872 ... 114.9		108960 ... 144.2		20
	133096 ... 47.4		125660 ... 66.7		119316 ... 89.4		113785 ... 115.4		108882 ... 144.7		
11	132961 ... 47.6		125546 ... 67.1		119218 ... 89.8		113699 ... 115.9		108805 ... 145.2		19
	132826 ... 47.9		125433 ... 67.4		119120 ... 90.2		113612 ... 116.3		108728 ... 145.8		
12	132692 ... 48.2		125320 ... 67.8		119022 ... 90.6		113526 ... 116.8		108651 ... 146.3		18
	132558 ... 48.5		125207 ... 68.1		118925 ... 91.0		113440 ... 117.3		108574 ... 146.8		
13	132425 ... 48.8		125094 ... 68.5		118827 ... 91.4		113354 ... 117.7		108498 ... 147.3		17
	132292 ... 49.1		124982 ... 68.8		118730 ... 91.8		113269 ... 118.2		108421 ... 147.8		
14	132159 ... 49.4		124870 ... 69.2		118633 ... 92.3		113183 ... 118.7		108345 ... 148.4		16
	132027 ... 49.7		124759 ... 69.6		118537 ... 92.7		113098 ... 119.1		108269 ... 148.9		
15	131896 ... 50.0		124647 ... 69.9		118440 ... 93.1		113013 ... 119.6		108193 ... 149.4		15
	131764 ... 50.3		124536 ... 70.3		118344 ... 93.5		112928 ... 120.1		108117 ... 149.9		
16	131633 ... 50.7		124425 ... 70.6		118248 ... 93.9		112843 ... 120.5		108041 ... 150.5		14
	131503 ... 51.0		124315 ... 71.0		118152 ... 94.3		112759 ... 121.0		107965 ... 151.0		
17	131373 ... 51.3		124204 ... 71.3		118056 ... 94.7		112674 ... 121.5		107890 ... 151.5		13
	131243 ... 51.6		124095 ... 71.7		117961 ... 95.2		112590 ... 121.9		107814 ... 152.1		
18	131114 ... 51.9		123985 ... 72.1		117866 ... 95.6		112506 ... 122.4		107739 ... 152.6		12
	130985 ... 52.2		123875 ... 72.4		117771 ... 96.0		112422 ... 122.9		107664 ... 153.1		
19	130856 ... 52.5		123766 ... 72.8		117676 ... 96.4		112338 ... 123.4		107589 ... 153.6		11
	130728 ... 52.8		123657 ... 73.2		117581 ... 96.9		112255 ... 123.9		107514 ... 154.2		
20	130600 ... 53.1		123549 ... 73.5		117487 ... 97.3		112171 ... 124.3		107439 ... 154.7		10
	130473 ... 53.4		123441 ... 73.9		117393 ... 97.7		112088 ... 124.8		107364 ... 155.2		
21	130346 ... 53.7		123332 ... 74.3		117299 ... 98.1		112005 ... 125.3		107290 ... 155.8		9
	130219 ... 54.1		123225 ... 74.6		117205 ... 98.5		111922 ... 125.8		107216 ... 156.3		
22	130093 ... 54.4		123117 ... 75.0		117112 ... 99.0		111839 ... 126.2		107141 ... 156.9		8
	129967 ... 54.7		123010 ... 75.4		117018 ... 99.4		111757 ... 126.7		107067 ... 157.4		
23	129841 ... 55.0		122903 ... 75.8		116925 ... 99.8		111674 ... 127.2		106993 ... 157.9		7
	129716 ... 55.3		122796 ... 76.1		116832 ... 100.3		111592 ... 127.7		106919 ... 158.5		
24	129591 ... 55.7		122690 ... 76.5		116739 ... 100.7		111510 ... 128.2		106846 ... 159.0		6
	129466 ... 56.0		122584 ... 76.9		116647 ... 101.1		111428 ... 128.7		106772 ... 159.6		
25	129342 ... 56.3		122478 ... 77.3		116554 ... 101.6		111346 ... 129.2		106698 ... 160.1		5
	129218 ... 56.6		122372 ... 77.6		116462 ... 102.0		111264 ... 129.7		106625 ... 160.6		
26	129095 ... 56.9		122267 ... 78.0		116370 ... 102.4		111183 ... 130.1		106552 ... 161.2		4
	128972 ... 57.3		122161 ... 78.4		116278 ... 102.9		111101 ... 130.6		106479 ... 161.7		
27	128849 ... 57.6		122057 ... 78.8		116187 ... 103.3		111020 ... 131.1		106406 ... 162.3		3
	128727 ... 57.9		121952 ... 79.2		116096 ... 103.7		110939 ... 131.6		106333 ... 162.8		
28	128605 ... 58.2		121848 ... 79.5		116004 ... 104.2		110858 ... 132.1		106260 ... 163.4		2
	128483 ... 58.6		121743 ... 79.9		115913 ... 104.6		110777 ... 132.6		106187 ... 163.9		
29	128362 ... 58.9		121639 ... 80.3		115823 ... 105.0		110696 ... 133.1		106115 ... 164.5		1
	128240 ... 59.2		121536 ... 80.7		115732 ... 105.5		110616 ... 133.6		106043 ... 165.0		
30	128120 ... 59.6		121432 ... 81.1		115641 ... 105.9		110536 ... 134.1		105970 ... 165.6		0
	A	B	A	B	A	B	A	B	A	B	
	177°00'		176°30'		176°00'		175°30'		175°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	5°00'		5°30'		6°00'		6°30'		7°00'		
	A	B	A	B	A	B	A	B	A	B	
0	105970 ... 165.6		101843 ... 200.4		98076 ... 239		94614 ... 280		91411 ... 325		30
	105898 ... 166.1		101777 ... 201.0		98017 ... 239		94559 ... 281		91359 ... 326		
1	105826 ... 166.7		101712 ... 201.6		97957 ... 240		94503 ... 281		91308 ... 326		29
	105754 ... 167.2		101646 ... 202.2		97897 ... 241		94448 ... 282		91257 ... 327		
2	105683 ... 167.8		101581 ... 202.8		97837 ... 241		94393 ... 283		91205 ... 328		28
	105611 ... 168.4		101516 ... 203.5		97777 ... 242		94338 ... 284		91154 ... 329		
3	105539 ... 168.9		101451 ... 204.1		97717 ... 243		94283 ... 284		91103 ... 330		27
	105468 ... 169.4		101386 ... 204.7		97658 ... 243		94228 ... 285		91052 ... 330		
4	105397 ... 170.0		101321 ... 205.3		97598 ... 244		94173 ... 286		91001 ... 331		26
	105325 ... 170.6		101256 ... 205.9		97539 ... 245		94118 ... 287		90950 ... 332		
5	105254 ... 171.1		101192 ... 206.5		97480 ... 245		94063 ... 287		90899 ... 333		25
	105183 ... 171.7		101127 ... 207.1		97420 ... 246		94009 ... 288		90848 ... 333		
6	105113 ... 172.3		101063 ... 207.8		97361 ... 247		93954 ... 289		90798 ... 334		24
	105042 ... 172.8		100998 ... 208.4		97302 ... 247		93899 ... 289		90747 ... 335		
7	104971 ... 173.4		100934 ... 209.0		97243 ... 248		93845 ... 290		90696 ... 336		23
	104901 ... 174.0		100870 ... 209.6		97184 ... 249		93790 ... 291		90646 ... 337		
8	104830 ... 174.5		100806 ... 210.3		97126 ... 249		93736 ... 292		90595 ... 337		22
	104760 ... 175.1		100742 ... 210.9		97067 ... 250		93682 ... 292		90545 ... 338		
9	104690 ... 175.7		100678 ... 211.5		97008 ... 251		93628 ... 293		90494 ... 339		21
	104620 ... 176.2		100614 ... 212.1		96950 ... 251		93573 ... 294		90444 ... 340		
10	104550 ... 176.8		100550 ... 212.8		96891 ... 252		93519 ... 295		90394 ... 341		20
	104480 ... 177.4		100487 ... 213.4		96833 ... 253		93465 ... 295		90344 ... 341		
11	104411 ... 178.0		100423 ... 214.0		96774 ... 253		93411 ... 296		90293 ... 342		19
	104341 ... 178.5		100360 ... 214.6		96716 ... 254		93358 ... 297		90243 ... 343		
12	104272 ... 179.1		100296 ... 215.3		96658 ... 255		93304 ... 298		90193 ... 344		18
	104202 ... 179.7		100233 ... 215.9		96600 ... 255		93250 ... 298		90143 ... 345		
13	104133 ... 180.3		100170 ... 216.5		96542 ... 256		93196 ... 299		90093 ... 345		17
	104064 ... 180.8		100107 ... 217.2		96484 ... 257		93143 ... 300		90044 ... 346		
14	103995 ... 181.4		100044 ... 217.8		96426 ... 257		93089 ... 301		89994 ... 347		16
	103926 ... 182.0		99981 ... 218.4		96368 ... 258		93036 ... 301		89944 ... 348		
15	103857 ... 182.6		99918 ... 219.1		96310 ... 259		92982 ... 302		89894 ... 349		15
	103788 ... 183.2		99856 ... 219.7		96253 ... 260		92929 ... 303		89845 ... 349		
16	103720 ... 183.7		99793 ... 220.3		96195 ... 260		92876 ... 304		89795 ... 350		14
	103651 ... 184.3		99731 ... 221.0		96138 ... 261		92823 ... 304		89746 ... 351		
17	103583 ... 184.9		99668 ... 221.6		96080 ... 262		92769 ... 305		89696 ... 352		13
	103515 ... 185.5		99606 ... 222.3		96023 ... 262		92716 ... 306		89647 ... 353		
18	103447 ... 186.1		99544 ... 222.9		95966 ... 263		92663 ... 307		89597 ... 353		12
	103379 ... 186.7		99481 ... 223.5		95909 ... 264		92610 ... 307		89548 ... 354		
19	103311 ... 187.2		99420 ... 224.2		95851 ... 264		92558 ... 308		89499 ... 355		11
	103243 ... 187.8		99357 ... 224.8		95795 ... 265		92505 ... 309		89450 ... 356		
20	103175 ... 188.4		99296 ... 225.5		95737 ... 266		92452 ... 310		89401 ... 357		10
	103107 ... 189.0		99234 ... 226.1		95681 ... 267		92399 ... 310		89352 ... 357		
21	103040 ... 189.6		99172 ... 226.8		95624 ... 267		92347 ... 311		89303 ... 358		9
	102973 ... 190.2		99110 ... 227.4		95567 ... 268		92294 ... 312		89254 ... 359		
22	102905 ... 190.8		99049 ... 228.1		95510 ... 269		92242 ... 313		89205 ... 360		8
	102838 ... 191.4		98988 ... 228.7		95454 ... 269		92189 ... 313		89156 ... 361		
23	102771 ... 192.0		98926 ... 229.4		95397 ... 270		92137 ... 314		89107 ... 362		7
	102704 ... 192.6		98865 ... 230.0		95341 ... 271		92085 ... 315		89059 ... 362		
24	102637 ... 193.2		98804 ... 230.7		95285 ... 271		92032 ... 316		89010 ... 363		6
	102570 ... 193.8		98743 ... 231.3		95228 ... 272		91980 ... 316		88961 ... 364		
25	102504 ... 194.4		98682 ... 232.0		95172 ... 273		91928 ... 317		88913 ... 365		5
	102437 ... 195.0		98621 ... 232.6		95116 ... 274		91876 ... 318		88864 ... 366		
26	102371 ... 195.6		98560 ... 233.3		95060 ... 274		91824 ... 319		88816 ... 366		4
	102304 ... 196.2		98499 ... 233.9		95004 ... 275		91772 ... 319		88767 ... 367		
27	102238 ... 196.8		98439 ... 234.6		94948 ... 276		91720 ... 320		88719 ... 368		3
	102172 ... 197.4		98378 ... 235.3		94892 ... 276		91668 ... 321		88671 ... 369		
28	102106 ... 198.0		98318 ... 235.9		94836 ... 277		91617 ... 322		88623 ... 370		2
	102040 ... 198.6		98257 ... 236.6		94781 ... 278		91565 ... 323		88574 ... 371		
29	101974 ... 199.2		98197 ... 237.2		94725 ... 279		91514 ... 323		88526 ... 371		1
	101908 ... 199.8		98137 ... 237.9		94670 ... 279		91462 ... 324		88478 ... 372		
30	101843 ... 200.4		98076 ... 238.6		94614 ... 280		91411 ... 325		88430 ... 373		0
	A	B	A	B	A	B	A	B	A	B	
	174°30'		174°00'		173°30'		173°00'		172°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	7°30'		8°00'		8°30'		9°00'		9°30'		
	A	B	A	B	A	B	A	B	A	B	
0	88430	373	85644	425	83030	480	80567	538	78239	600	30
1	88382	374	85599	426	82987	481	80527	539	78201	601	29
	88334	375	85555	428	82945	482	80487	540	78184	602	
	88286	376	85510	427	82903	482	80447	541	78128	603	
2	88239	376	85465	428	82861	483	80407	542	78088	604	28
3	88191	377	85420	429	82819	484	80368	543	78051	605	27
	88143	378	85376	430	82777	485	80328	544	78013	606	
	88096	379	85331	431	82735	486	80288	545	77976	607	
4	88048	380	85286	432	82693	487	80249	548	77938	608	28
5	88001	381	85242	433	82651	488	80209	547	77901	609	25
	87953	381	85197	434	82609	489	80170	548	77863	610	
	87906	382	85153	434	82567	490	80130	549	77826	611	
6	87858	383	85108	435	82526	491	80091	550	77788	612	24
7	87811	384	85064	436	82484	492	80051	551	77751	614	23
	87764	385	85020	437	82442	493	80012	552	77714	615	
	87716	386	84976	438	82400	494	79973	553	77677	618	
8	87669	387	84931	439	82359	495	79933	554	77639	617	22
9	87622	387	84887	440	82317	496	79894	555	77602	618	21
	87575	388	84843	441	82276	497	79855	556	77565	619	
	87528	389	84799	442	82234	498	79816	557	77528	620	
10	87481	390	84755	443	82193	499	79777	558	77491	621	20
11	87434	391	84711	444	82151	500	79737	559	77454	622	19
	87387	392	84667	444	82110	501	79698	560	77417	623	
	87341	392	84623	445	82069	502	79659	561	77380	624	
12	87294	393	84579	446	82027	503	79620	562	77343	625	18
13	87247	394	84535	447	81986	504	79581	563	77306	626	17
	87201	395	84492	448	81945	504	79542	564	77269	627	
	87154	396	84448	449	81904	505	79503	565	77232	629	
14	87107	397	84404	450	81863	506	79465	566	77195	630	16
15	87061	398	84361	451	81821	507	79426	567	77158	631	15
	87015	399	84317	452	81780	508	79387	568	77122	632	
	86968	399	84273	453	81739	509	79348	569	77085	633	
16	86922	400	84230	454	81698	510	79309	570	77048	634	14
17	86876	401	84186	454	81657	511	79271	571	77011	635	13
	86829	402	84143	455	81617	512	79232	573	76975	636	
	86783	403	84100	456	81576	513	79193	574	76938	637	
18	86737	404	84056	457	81535	514	79155	575	76902	638	12
19	86691	405	84013	458	81494	515	79116	576	76865	639	11
	86645	405	83970	459	81453	516	79078	577	76828	641	
	86599	406	83927	460	81413	517	79039	578	76792	642	
20	86553	407	83884	461	81372	518	79001	579	76756	643	10
21	86507	408	83840	462	81331	519	78962	580	76719	644	9
	86461	409	83797	463	81291	520	78924	581	76683	645	
	86415	410	83754	464	81250	521	78886	582	76646	646	
22	86370	411	83711	465	81210	522	78847	583	76610	647	8
23	86324	411	83668	466	81169	523	78809	584	76574	648	7
	86278	412	83626	467	81129	524	78771	585	76537	649	
	86233	413	83583	467	81088	525	78733	586	76501	650	
24	86187	414	83540	468	81048	526	78694	587	76465	652	6
25	86142	415	83497	469	81008	527	78656	588	76429	653	5
	86096	416	83455	470	80967	528	78618	589	76393	654	
	86051	417	83412	471	80927	529	78580	590	76357	655	
26	86006	418	83369	472	80887	530	78542	591	76320	656	4
27	85960	418	83327	473	80847	531	78504	592	76284	657	3
	85915	419	83284	474	80807	532	78466	593	76248	658	
	85870	420	83242	475	80767	533	78428	594	76212	659	
28	85825	421	83199	476	80727	534	78390	595	76176	660	2
29	85779	422	83157	477	80687	535	78352	597	76141	661	1
	85734	423	83114	478	80647	536	78315	598	76105	663	
	85689	424	83072	479	80607	537	78277	599	76069	664	
30	85644	425	83030	480	80567	538	78239	600	76033	665	0
	A	B	A	B	A	B	A	B	A	B	
	172°00'		171°30'		171°00'		170°30'		170°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	10°00'		10°30'		11°00'		11°30'		12°00'		
	A	B	A	B	A	B	A	B	A	B	
0	76033	.665	73937	.733	71940	.805	70034	.881	68212	.960	30
1	75997	.666	73903	.735	71908	.807	70003	.882	68182	.961	29
	75961	.667	73869	.736	71875	.808	69972	.883	68153	.962	
2	75926	.668	73835	.737	71843	.809	69941	.885	68123	.964	28
	75890	.669	73801	.738	71810	.810	69910	.886	68093	.965	
3	75854	.670	73767	.739	71778	.811	69879	.887	68064	.966	27
	75819	.672	73733	.740	71746	.813	69849	.888	68034	.968	
4	75783	.673	73699	.742	71713	.814	69818	.890	68005	.969	26
	75747	.674	73665	.743	71681	.815	69787	.891	67975	.970	
5	75712	.675	73631	.744	71649	.816	69756	.892	67945	.972	25
	75676	.676	73597	.745	71616	.818	69725	.894	67916	.973	
6	75641	.677	73563	.746	71584	.819	69694	.895	67886	.974	24
	75605	.678	73530	.747	71552	.820	69664	.896	67857	.976	
7	75570	.679	73496	.749	71520	.821	69633	.897	67828	.977	23
	75534	.680	73462	.750	71488	.823	69602	.899	67798	.978	
8	75499	.682	73429	.751	71455	.824	69571	.900	67769	.980	22
	75464	.683	73395	.752	71423	.825	69541	.901	67739	.981	
9	75428	.684	73361	.753	71391	.826	69510	.903	67710	.982	21
	75393	.685	73328	.755	71359	.828	69479	.904	67681	.984	
10	75358	.686	73294	.756	71327	.829	69449	.905	67651	.985	20
	75322	.687	73260	.757	71295	.830	69418	.907	67622	.987	
11	75287	.688	73227	.758	71263	.831	69387	.908	67593	.988	19
	75252	.690	73193	.759	71231	.833	69357	.909	67563	.989	
12	75217	.691	73160	.761	71199	.834	69326	.910	67534	.991	18
	75182	.692	73127	.762	71167	.835	69296	.912	67505	.992	
13	75147	.693	73093	.763	71135	.836	69265	.913	67476	.993	17
	75112	.694	73060	.764	71104	.838	69235	.914	67447	.995	
14	75077	.695	73026	.765	71072	.839	69204	.916	67417	.996	16
	75042	.696	72993	.766	71040	.840	69174	.917	67388	.997	
15	75007	.698	72960	.768	71008	.841	69144	.918	67359	.999	15
	74972	.699	72926	.769	70976	.843	69113	.920	67330	.1000	
16	74937	.700	72893	.770	70945	.844	69083	.921	67301	.1002	14
	74902	.701	72860	.771	70913	.845	69053	.922	67272	.1003	
17	74867	.702	72827	.772	70881	.846	69022	.924	67243	.1004	13
	74832	.703	72794	.774	70850	.848	68992	.925	67214	.1006	
18	74797	.704	72760	.775	70818	.849	68962	.926	67185	.1007	12
	74763	.706	72727	.776	70786	.850	68931	.928	67156	.1008	
19	74728	.707	72694	.777	70755	.851	68901	.929	67127	.1010	11
	74693	.708	72661	.779	70723	.853	68871	.930	67098	.1011	
20	74659	.709	72628	.780	70692	.854	68841	.932	67069	.1013	10
	74624	.710	72595	.781	70660	.855	68811	.933	67040	.1014	
21	74589	.711	72562	.782	70629	.856	68781	.934	67011	.1015	9
	74555	.712	72529	.783	70597	.858	68750	.935	66982	.1017	
22	74520	.714	72496	.785	70566	.859	68720	.937	66953	.1018	8
	74486	.715	72463	.786	70534	.860	68690	.938	66925	.1020	
23	74451	.716	72430	.787	70503	.862	68660	.939	66896	.1021	7
	74417	.717	72397	.788	70471	.863	68630	.941	66867	.1022	
24	74382	.718	72365	.790	70440	.864	68600	.942	66838	.1024	6
	74348	.719	72332	.791	70409	.865	68570	.943	66810	.1025	
25	74313	.721	72299	.792	70377	.867	68540	.945	66781	.1026	5
	74279	.722	72266	.793	70346	.868	68510	.946	66752	.1028	
26	74245	.723	72234	.794	70315	.869	68480	.947	66724	.1029	4
	74210	.724	72201	.796	70284	.870	68450	.949	66695	.1031	
27	74176	.725	72168	.797	70252	.872	68421	.950	66666	.1032	3
	74142	.726	72135	.798	70221	.873	68391	.951	66638	.1033	
28	74107	.728	72103	.799	70190	.874	68361	.953	66609	.1035	2
	74073	.729	72070	.800	70159	.876	68331	.954	66580	.1036	
29	74039	.730	72038	.802	70128	.877	68301	.955	66552	.1038	1
	74005	.731	72005	.803	70097	.878	68272	.957	66523	.1039	
30	73971	.732	71973	.804	70065	.879	68242	.958	66495	.1040	0
	73937	.733	71940	.805	70034	.881	68212	.960	66466	.1042	
	A	B	A	B	A	B	A	B	A	B	
	169°30'		169°30'		168°30'		168°00'		167°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	12°30'		13°00'		13°30'		14°00'		14°30'		
	A	B	A	B	A	B	A	B	A	B	
0	66466	1042	64791	1128	63181	1217	61632	1310	60140	1406	30
	66438	1043	64764	1129	63155	1218	61607	1311	60118	1407	
1	66409	1045	64738	1130	63129	1220	61582	1313	60091	1409	29
	66381	1046	64709	1132	63103	1221	61556	1314	60067	1411	
2	66352	1047	64682	1133	63076	1223	61531	1318	60042	1412	28
	66324	1049	64655	1135	63050	1224	61506	1317	60018	1414	
3	66296	1050	64627	1136	63024	1228	61481	1319	59994	1416	27
	66267	1052	64600	1138	62998	1227	61455	1321	59969	1417	
4	66239	1053	64573	1139	62971	1229	61430	1322	59945	1419	26
	66211	1054	64546	1141	62945	1230	61405	1324	59921	1421	
5	66182	1056	64518	1142	62919	1232	61380	1325	59896	1422	25
	66154	1057	64491	1144	62893	1234	61355	1327	59872	1424	
6	66126	1059	64464	1145	62867	1235	61330	1329	59848	1425	24
	66098	1060	64437	1147	62841	1237	61304	1330	59824	1427	
7	66069	1061	64410	1148	62815	1238	61279	1332	59800	1429	23
	66041	1063	64383	1150	62789	1240	61254	1333	59775	1430	
8	66013	1064	64356	1151	62763	1241	61229	1335	59751	1432	22
	65985	1066	64329	1152	62737	1243	61204	1336	59727	1434	
9	65957	1067	64302	1154	62711	1244	61179	1338	59703	1435	21
	65928	1069	64275	1155	62685	1246	61154	1340	59679	1437	
10	65900	1070	64248	1157	62659	1247	61129	1341	59654	1439	20
	65872	1071	64221	1158	62633	1249	61104	1343	59630	1440	
11	65844	1073	64194	1160	62607	1250	61079	1344	59606	1442	19
	65816	1074	64167	1161	62581	1252	61054	1346	59582	1444	
12	65788	1076	64140	1163	62555	1253	61029	1348	59558	1445	18
	65760	1077	64113	1164	62529	1255	61004	1349	59534	1447	
13	65732	1079	64086	1166	62503	1257	60979	1351	59510	1449	17
	65704	1080	64059	1167	62477	1258	60954	1352	59486	1450	
14	65676	1081	64032	1169	62451	1260	60929	1354	59462	1452	16
	65648	1083	64005	1170	62425	1261	60904	1356	59438	1454	
15	65620	1084	63978	1172	62400	1263	60879	1357	59414	1455	15
	65592	1086	63952	1173	62374	1264	60855	1359	59390	1457	
16	65564	1087	63925	1175	62348	1266	60830	1360	59366	1459	14
	65537	1089	63898	1176	62322	1287	60805	1362	59342	1460	
17	65509	1090	63871	1178	62296	1269	60780	1364	59318	1462	13
	65481	1091	63845	1179	62271	1270	60755	1365	59294	1464	
18	65453	1093	63818	1181	62245	1272	60730	1367	59270	1465	12
	65425	1094	63791	1182	62219	1274	60706	1368	59246	1467	
19	65398	1096	63764	1184	62194	1275	60681	1370	59222	1469	11
	65370	1097	63738	1185	62168	1277	60656	1372	59198	1470	
20	65342	1099	63711	1187	62142	1278	60631	1373	59175	1472	10
	65314	1100	63684	1188	62117	1280	60607	1375	59151	1474	
21	65287	1101	63658	1190	62091	1281	60582	1377	59127	1475	9
	65259	1103	63631	1191	62065	1283	60557	1378	59103	1477	
22	65231	1104	63605	1193	62040	1284	60533	1380	59079	1479	8
	65204	1106	63578	1194	62014	1286	60508	1381	59055	1480	
23	65176	1107	63551	1196	61989	1288	60483	1383	59032	1482	7
	65148	1109	63525	1197	61963	1289	60459	1385	59008	1484	
24	65121	1110	63498	1199	61938	1291	60434	1386	58984	1485	6
	65093	1112	63472	1200	61912	1292	60410	1388	58960	1487	
25	65066	1113	63445	1202	61887	1294	60385	1390	58937	1489	5
	65038	1114	63419	1203	61861	1295	60360	1391	58913	1490	
26	65011	1116	63392	1205	61836	1297	60336	1393	58889	1492	4
	64983	1117	63366	1206	61810	1299	60311	1394	58866	1494	
27	64956	1119	63340	1208	61785	1300	60287	1396	58842	1495	3
	64928	1120	63313	1209	61759	1301	60262	1398	58818	1497	
28	64901	1122	63287	1211	61734	1303	60238	1399	58795	1499	2
	64873	1123	63260	1212	61709	1305	60213	1401	58771	1500	
29	64846	1125	63234	1214	61683	1306	60189	1403	58748	1502	1
	64819	1126	63208	1215	61658	1308	60164	1404	58724	1504	
30	64791	1128	63181	1217	61632	1310	60140	1406	58700	1506	0
	A	B	A	B	A	B	A	B	A	B	
	167°00'		166°30'		166°00'		165°30'		165°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	15°00'		15°30'		16°00'		16°30'		17°00'		
	A	B	A	B	B	B	A	B	A	B	
0	58700	1506	57310	1609	55966	1716	54666	1826	53406	1940	30
1	58677	1507	57287	1611	55944	1718	54644	1828	53386	1942	29
	58653	1509	57265	1612	55922	1719	54623	1830	53365	1944	
	58630	1511	57242	1614	55900	1721	54602	1832	53344	1946	
2	58606	1512	57219	1616	55878	1723	54581	1834	53324	1948	28
3	58583	1514	57196	1618	55856	1725	54559	1836	53303	1950	27
	58559	1516	57174	1619	55834	1727	54538	1837	53283	1952	
	58536	1517	57151	1621	55812	1728	54517	1839	53262	1954	
4	58512	1519	57128	1623	55790	1730	54496	1841	53241	1956	26
5	58489	1521	57106	1625	55768	1732	54474	1843	53221	1958	25
	58465	1523	57083	1627	55746	1734	54453	1845	53200	1960	
	58442	1524	57060	1628	55725	1736	54432	1847	53180	1962	
6	58418	1526	57038	1630	55703	1738	54411	1849	53159	1964	24
7	58395	1528	57015	1632	55681	1739	54390	1851	53139	1966	23
	58372	1529	56992	1634	55659	1741	54368	1853	53118	1967	
	58348	1531	56970	1635	55637	1743	54347	1854	53098	1969	
8	58325	1533	56947	1637	55615	1745	54326	1856	53077	1971	22
9	58302	1534	56925	1639	55593	1747	54305	1858	53057	1973	21
	58278	1536	56902	1641	55572	1749	54284	1860	53036	1975	
	58255	1538	56880	1642	55550	1750	54263	1862	53016	1977	
10	58232	1540	56857	1644	55528	1752	54242	1864	52995	1979	20
11	58208	1541	56835	1646	55506	1754	54220	1866	52975	1981	19
	58185	1543	56812	1648	55484	1756	54199	1868	52954	1983	
	58162	1545	56790	1649	55463	1758	54178	1870	52934	1985	
12	58138	1546	56767	1651	55441	1760	54157	1871	52914	1987	18
13	58115	1548	56745	1653	55419	1761	54136	1873	52893	1989	17
	58092	1550	56722	1655	55397	1763	54115	1875	52873	1991	
	58069	1552	56700	1657	55376	1765	54094	1877	52852	1993	
14	58046	1553	56677	1658	55354	1767	54073	1879	52832	1995	16
15	58022	1555	56655	1660	55332	1769	54052	1881	52812	1997	15
	57999	1557	56632	1662	55311	1771	54031	1883	52791	1999	
	57976	1559	56610	1664	55289	1772	54010	1885	52771	2001	
16	57953	1560	56588	1665	55267	1774	53989	1887	52751	2003	14
17	57930	1562	56565	1667	55246	1776	53968	1889	52730	2005	13
	57907	1564	56543	1669	55224	1778	53947	1890	52710	2007	
	57884	1565	56521	1671	55202	1780	53926	1892	52690	2009	
18	57860	1567	56498	1673	55181	1782	53905	1894	52670	2010	12
19	57837	1569	56476	1674	55159	1783	53884	1896	52649	2012	11
	57814	1571	56454	1676	55138	1785	53864	1898	52629	2014	
	57791	1572	56431	1678	55116	1787	53843	1900	52609	2016	
20	57768	1574	56409	1680	55095	1789	53822	1902	52588	2018	10
21	57745	1576	56387	1682	55073	1791	53801	1904	52568	2020	9
	57722	1578	56365	1683	55051	1793	53780	1906	52548	2022	
	57699	1579	56342	1685	55030	1795	53759	1908	52528	2024	
22	57676	1581	56320	1687	55008	1796	53738	1910	52508	2026	8
23	57653	1583	56298	1689	54987	1798	53718	1911	52487	2028	7
	57630	1584	56276	1691	54965	1800	53697	1913	52467	2030	
	57607	1586	56254	1692	54944	1802	53676	1915	52447	2032	
24	57584	1588	56231	1694	54922	1804	53655	1917	52427	2034	6
25	57561	1590	56209	1696	54901	1806	53634	1919	52407	2036	5
	57538	1591	56187	1698	54880	1808	53614	1921	52387	2038	
	57516	1593	56165	1700	54858	1809	53593	1923	52366	2040	
26	57493	1595	56143	1701	54837	1811	53572	1925	52346	2042	4
27	57470	1597	56121	1703	54815	1813	53551	1927	52326	2044	3
	57447	1598	56099	1705	54794	1815	53531	1929	52306	2046	
	57424	1600	56076	1707	54773	1817	53510	1931	52286	2048	
28	57401	1602	56054	1709	54751	1819	53489	1933	52266	2050	2
29	57378	1604	56032	1710	54730	1821	53468	1935	52246	2052	1
	57356	1605	56010	1712	54708	1823	53448	1936	52226	2054	
	57333	1607	55988	1714	54687	1824	53427	1938	52206	2056	
30	57310	1609	55966	1716	54666	1826	53406	1940	52186	2058	0
	A	B	A	B	A	B	A	B	A	B	
	164°30'		164°00'		163°30'		163°00'		162°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	17°30'		18°00'		18°30'		19°00'		19°30'		
	A	B	A	B	A	B	A	B	A	B	
0	52186	2058	51002	2179	49852	2304	48736	2433	47650	2585	30
	52166	2060	50982	2181	49833	2306	48717	2435	47633	2588	
1	52146	2062	50963	2183	49815	2309	48699	2437	47615	2570	29
	52126	2064	50943	2185	49796	2311	48681	2439	47597	2572	
2	52106	2066	50924	2188	49777	2313	48662	2442	47579	2574	28
	52086	2068	50905	2190	49758	2315	48644	2444	47561	2576	
3	52066	2070	50885	2192	49739	2317	48626	2446	47544	2579	27
	52046	2072	50866	2194	49720	2319	48608	2448	47526	2581	
4	52026	2074	50846	2196	49702	2321	48589	2450	47508	2583	26
	52006	2076	50827	2198	49683	2323	48571	2453	47490	2585	
5	51986	2078	50808	2200	49664	2325	48553	2455	47472	2588	25
	51966	2080	50788	2202	49645	2328	48534	2457	47455	2590	
6	51946	2082	50769	2204	49626	2330	48516	2459	47437	2592	24
	51926	2084	50750	2206	49608	2332	48498	2461	47419	2594	
7	51906	2086	50730	2208	49589	2334	48480	2463	47402	2597	23
	51886	2088	50711	2210	49570	2336	48462	2466	47384	2599	
8	51867	2090	50692	2212	49551	2338	48443	2468	47366	2601	22
	51847	2092	50673	2214	49533	2340	48425	2470	47348	2603	
9	51827	2094	50653	2216	49514	2343	48407	2472	47331	2606	21
	51807	2096	50634	2218	49495	2345	48389	2474	47313	2608	
10	51787	2098	50615	2221	49477	2347	48371	2477	47295	2610	20
	51767	2100	50596	2223	49458	2349	48352	2479	47278	2613	
11	51747	2102	50576	2225	49439	2351	48334	2481	47260	2615	19
	51728	2104	50557	2227	49421	2353	48316	2483	47242	2617	
12	51708	2106	50538	2229	49402	2355	48298	2485	47225	2619	18
	51688	2108	50519	2231	49383	2357	48280	2488	47207	2622	
13	51668	2110	50499	2233	49365	2360	48262	2490	47189	2624	17
	51649	2112	50480	2235	49346	2362	48244	2492	47172	2626	
14	51629	2114	50461	2237	49327	2364	48225	2494	47154	2628	16
	51609	2116	50442	2239	49309	2366	48207	2496	47137	2631	
15	51589	2118	50423	2241	49290	2368	48189	2499	47119	2633	15
	51570	2120	50404	2243	49271	2370	48171	2501	47101	2635	
16	51550	2122	50385	2246	49253	2372	48153	2503	47084	2637	14
	51530	2124	50365	2248	49234	2375	48135	2505	47066	2640	
17	51510	2126	50346	2250	49216	2377	48117	2507	47049	2642	13
	51491	2128	50327	2252	49197	2379	48099	2510	47031	2644	
18	51471	2130	50308	2254	49179	2381	48081	2512	47014	2646	12
	51451	2132	50289	2256	49160	2383	48063	2514	46996	2649	
19	51432	2134	50270	2258	49141	2385	48045	2516	46978	2651	11
	51412	2136	50251	2260	49123	2387	48027	2519	46961	2653	
20	51392	2138	50232	2262	49104	2390	48009	2521	46943	2656	10
	51373	2141	50213	2264	49086	2392	47991	2523	46926	2658	
21	51353	2143	50194	2266	49067	2394	47973	2525	46908	2660	9
	51334	2145	50175	2269	49049	2396	47955	2527	46891	2662	
22	51314	2147	50156	2271	49030	2398	47937	2530	46873	2665	8
	51294	2149	50137	2273	49012	2400	47919	2532	46856	2667	
23	51275	2151	50117	2275	48993	2403	47901	2534	46839	2669	7
	51255	2153	50098	2277	48975	2405	47883	2536	46821	2672	
24	51236	2155	50080	2279	48957	2407	47865	2539	46804	2674	6
	51216	2157	50061	2281	48938	2409	47847	2541	46786	2676	
25	51197	2159	50042	2283	48920	2411	47829	2543	46769	2678	5
	51177	2161	50023	2285	48901	2413	47811	2545	46751	2681	
26	51158	2163	50004	2287	48883	2416	47793	2547	46734	2683	4
	51138	2165	49985	2290	48864	2418	47775	2550	46716	2685	
27	51119	2167	49966	2292	48846	2420	47758	2552	46699	2688	3
	51099	2169	49947	2294	48828	2422	47740	2554	46682	2690	
28	51080	2171	49928	2296	48809	2424	47722	2556	46664	2692	2
	51060	2173	49909	2298	48791	2426	47704	2559	46647	2694	
29	51041	2175	49890	2300	48772	2429	47686	2561	46630	2697	1
	51021	2177	49871	2302	48754	2431	47668	2563	46612	2699	
30	51002	2179	49852	2304	48736	2433	47650	2565	46595	2701	0
	A	B	A	B	A	B	A	B	A	B	
	162°00'		161°30'		161°00'		160°30'		160°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	20°00'		20°30'		21°00'		21°30'		22°00'		
	A	B	A	B	A	B	A	B	A	B	
0	46595	2701	45567	2841	44567	2985	43592	3132	42642	3283	30
	46577	2704	45551	2844	44551	2988	43576	3135	42627	3288	
1	46560	2706	45534	2846	44534	2990	43560	3137	42611	3293	29
	46543	2708	45517	2848	44518	2992	43544	3140	42596	3291	
2	46525	2711	45500	2851	44501	2994	43528	3142	42580	3294	28
	46508	2713	45483	2853	44485	2997	43512	3145	42564	3298	
3	46491	2715	45466	2855	44468	2999	43496	3147	42549	3299	27
	46473	2717	45449	2858	44452	3002	43480	3150	42533	3301	
4	46456	2720	45433	2860	44436	3004	43464	3152	42518	3304	26
	46439	2722	45416	2862	44419	3007	43448	3155	42502	3305	
5	46422	2724	45399	2865	44403	3009	43432	3157	42486	3309	25
	46404	2727	45382	2867	44386	3012	43416	3160	42471	3312	
6	46387	2729	45365	2870	44370	3014	43400	3162	42455	3314	24
	46370	2731	45348	2872	44354	3016	43385	3165	42449	3317	
7	46353	2734	45332	2874	44337	3019	43369	3167	42424	3319	23
	46335	2736	45315	2877	44321	3021	43353	3170	42409	3322	
8	46318	2738	45298	2879	44305	3024	43337	3172	42393	3324	22
	46301	2741	45281	2881	44288	3026	43321	3175	42378	3327	
9	46284	2743	45265	2884	44272	3029	43305	3177	42362	3329	21
	46266	2745	45248	2886	44256	3031	43289	3180	42347	3332	
10	46249	2748	45231	2889	44239	3033	43273	3182	42331	3335	20
	46232	2750	45214	2891	44223	3036	43257	3185	42316	3337	
11	46215	2752	45198	2893	44207	3038	43241	3187	42300	3340	19
	46198	2755	45181	2896	44190	3041	43225	3190	42285	3342	
12	46181	2757	45164	2898	44174	3043	43210	3192	42269	3345	18
	46163	2759	45147	2901	44158	3046	43194	3195	42254	3347	
13	46146	2761	45131	2903	44142	3048	43178	3197	42238	3350	17
	46129	2764	45114	2905	44125	3051	43162	3200	42223	3353	
14	46112	2766	45097	2908	44109	3053	43146	3202	42207	3355	16
	46095	2768	45081	2910	44093	3056	43130	3205	42192	3358	
15	46078	2771	45064	2913	44077	3058	43114	3207	42176	3360	15
	46061	2773	45047	2915	44060	3060	43099	3210	42161	3363	
16	46043	2775	45031	2917	44044	3063	43083	3212	42145	3366	14
	46026	2778	45014	2920	44028	3065	43067	3215	42130	3368	
17	46009	2780	44997	2922	44012	3068	43051	3217	42115	3371	13
	45992	2782	44981	2924	43995	3070	43035	3220	42099	3373	
18	45975	2785	44964	2927	43979	3073	43020	3222	42084	3376	12
	45958	2787	44947	2929	43963	3075	43004	3225	42068	3379	
19	45941	2789	44931	2932	43947	3078	42988	3227	42053	3381	11
	45924	2792	44914	2934	43931	3080	42972	3230	42038	3384	
20	45907	2794	44898	2936	43914	3083	42956	3233	42022	3386	10
	45890	2797	44881	2939	43898	3085	42941	3235	42007	3389	
21	45873	2799	44864	2941	43882	3088	42925	3238	41991	3391	9
	45856	2801	44848	2944	43866	3090	42909	3240	41976	3394	
22	45839	2804	44831	2946	43850	3092	42893	3243	41961	3397	8
	45822	2806	44815	2949	43834	3095	42878	3245	41945	3399	
23	45805	2808	44798	2951	43818	3097	42862	3248	41930	3402	7
	45788	2811	44782	2953	43801	3100	42846	3250	41915	3404	
24	45771	2813	44765	2956	43785	3102	42830	3253	41899	3407	6
	45754	2815	44748	2958	43769	3105	42815	3255	41884	3410	
25	45737	2818	44732	2961	43753	3107	42799	3258	41869	3412	5
	45720	2820	44715	2963	43737	3110	42783	3260	41853	3415	
26	45703	2822	44699	2965	43721	3112	42768	3263	41838	3418	4
	45686	2835	44682	2968	43705	3115	42752	3266	41823	3420	
27	45669	2827	44666	2970	43689	3117	42736	3268	41808	3423	3
	45652	2829	44649	2973	43673	3120	42721	3271	41792	3425	
28	45635	2832	44633	2975	43657	3122	42705	3273	41777	3428	2
	45618	2834	44616	2978	43641	3125	42689	3276	41762	3431	
29	45601	2836	44600	2980	43624	3127	42674	3278	41746	3433	1
	45584	2839	44583	2982	43608	3130	42658	3281	41731	3436	
30	45567	2841	44567	2985	43592	3132	42642	3283	41716	3438	0
	A	B	A	B	A	B	A	B	A	B	
	159°30'		159°00'		158°30'		158°00'		157°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	22°30'		23°00'		23°30'		24°00'		24°30'		
	A	B	A	B	A	B	A	B	A	B	
0	41716 3438		40812 3597		39930 3760		39089 3927		38227 4098		30
	41701 3441		40797 3600		39915 3763		39054 3930		38213 4101		
1	41685 3444		40782 3603		39901 3766		39040 3932		38200 4103		29
	41670 3448		40788 3605		39886 3768		39028 3935		38186 4106		
2	41655 3449		40753 3608		39872 3771		39012 3938		38172 4109		28
	41640 3452		40738 3611		39857 3774		38998 3941		38158 4112		
3	41625 3454		40723 3613		39843 3777		38984 3944		38144 4115		27
	41609 3457		40708 3618		39828 3779		38969 3947		38130 4118		
4	41594 3459		40693 3619		39814 3782		38955 3949		38117 4121		26
	41579 3462		40678 3622		39799 3785		38941 3952		38103 4124		
5	41564 3465		40664 3624		39785 3788		38927 3955		38089 4127		25
	41549 3487		40649 3627		39771 3790		38913 3958		38075 4129		
6	41533 3470		40634 3630		39756 3793		38899 3981		38061 4132		24
	41518 3473		40619 3632		39742 3796		38885 3964		38048 4135		
7	41503 3475		40604 3635		39727 3799		38871 3966		38034 4138		23
	41488 3478		40590 3638		39713 3801		38856 3969		38020 4141		
8	41473 3480		40575 3640		39698 3804		38842 3972		38006 4144		22
	41458 3483		40560 3643		39684 3807		38828 3975		37992 4147		
9	41443 3486		40545 3646		39669 3810		38814 3978		37979 4150		21
	41427 3488		40530 3648		39655 3813		38800 3981		37965 4153		
10	41412 3491		40516 3651		39641 3815		38786 3983		37951 4155		20
	41397 3494		40501 3654		39626 3818		38772 3986		37937 4158		
11	41382 3498		40486 3657		39612 3821		38758 3989		37924 4161		19
	41367 3499		40471 3659		39597 3824		38744 3992		37910 4164		
12	41352 3502		40457 3662		39583 3826		38730 3995		37896 4167		18
	41337 3504		40442 3665		39569 3829		38716 3998		37882 4170		
13	41322 3507		40427 3667		39554 3832		38702 4000		37869 4173		17
	41307 3509		40413 3670		39540 3835		38688 4003		37855 4176		
14	41291 3512		40398 3873		39525 3838		38674 4006		37841 4179		16
	41276 3515		40383 3876		39511 3840		38660 4009		37828 4182		
15	41261 3517		40368 3878		39497 3843		38645 4012		37814 4185		15
	41246 3520		40354 3881		39482 3846		38631 4015		37800 4187		
16	41231 3523		40339 3884		39468 3849		38617 4017		37786 4190		14
	41216 3525		40324 3886		39454 3851		38603 4020		37773 4193		
17	41201 3528		40310 3889		39439 3854		38589 4023		37759 4196		13
	41186 3531		40295 3892		39425 3857		38575 4026		37745 4199		
18	41171 3533		40280 3895		39411 3860		38561 4029		37732 4202		12
	41156 3536		40266 3897		39396 3863		38547 4032		37718 4205		
19	41141 3539		40251 3700		39382 3865		38533 4035		37704 4208		11
	41126 3541		40236 3703		39368 3868		38520 4037		37691 4211		
20	41111 3544		40222 3705		39353 3871		38506 4040		37677 4214		10
	41096 3547		40207 3708		39339 3874		38492 4043		37663 4217		
21	41081 3549		40192 3711		39325 3876		38478 4046		37650 4220		9
	41066 3552		40178 3714		39311 3879		38464 4049		37636 4222		
22	41051 3555		40163 3716		39296 3882		38450 4052		37623 4225		8
	41036 3557		40149 3719		39282 3885		38436 4055		37609 4228		
23	41021 3560		40134 3722		39268 3888		38422 4057		37595 4231		7
	41006 3563		40119 3725		39254 3890		38408 4060		37582 4234		
24	40991 3565		40105 3727		39239 3893		38394 4063		37568 4237		6
	40976 3568		40090 3730		39225 3896		38380 4066		37554 4240		
25	40961 3571		40076 3733		39211 3899		38368 4069		37541 4243		5
	40946 3573		40061 3735		39197 3902		38352 4072		37527 4246		
26	40931 3578		40046 3738		39182 3904		38338 4075		37514 4249		4
	40916 3579		40032 3741		39168 3907		38324 4078		37500 4252		
27	40902 3581		40017 3744		39154 3910		38311 4080		37486 4255		3
	40887 3584		40003 3746		39140 3913		38297 4083		37473 4258		
28	40872 3587		39988 3749		39125 3916		38283 4086		37459 4261		2
	40857 3589		39974 3752		39111 3918		38269 4089		37446 4264		
29	40842 3592		39959 3755		39097 3921		38255 4092		37432 4266		1
	40827 3595		39945 3757		39083 3924		38241 4095		37419 4269		
30	40812 3597		39930 3760		39069 3927		38227 4098		37405 4272		0
	A	B	A	B	A	B	A	B	A	B	
	157°00'		156°30'		156°00'		155°30'		155°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	25°00'		25°30'		26°00'		26°30'		27°00'		
	A	B	A	B	A	B	A	B	A	B	
0	37405	4272	36602	4451	35816	4634	35047	4821	34295	5012	30
1	37392	4275	36588	4454	35803	4637	35035	4824	34283	5015	29
	37378	4278	36575	4457	35790	4640	35022	4827	34270	5018	
2	37365	4281	36562	4460	35777	4643	35009	4830	34258	5022	
	37351	4284	36549	4463	35764	4646	34997	4833	34246	5025	28
3	37337	4287	36535	4466	35751	4649	34984	4837	34233	5028	
	37324	4290	36522	4469	35738	4651	34971	4840	34221	5031	27
4	37310	4293	36509	4472	35725	4656	34959	4843	34209	5034	
	37297	4296	36496	4475	35712	4659	34946	4846	34196	5038	26
5	37283	4299	36483	4478	35699	4662	34933	4849	34184	5041	
	37270	4302	36469	4481	35686	4665	34921	4852	34172	5044	25
6	37256	4305	36456	4484	35674	4668	34908	4856	34159	5047	
	37243	4308	36443	4487	35661	4671	34896	4859	34147	5051	24
7	37229	4311	36430	4490	35648	4674	34883	4862	34134	5054	
	37216	4314	36417	4493	35635	4677	34870	4865	34122	5057	23
8	37203	4317	36403	4496	35622	4680	34858	4868	34110	5060	
	37189	4320	36390	4499	35609	4683	34845	4871	34097	5064	22
9	37176	4323	36377	4503	35596	4686	34832	4875	34085	5067	
	37162	4326	36364	4506	35583	4690	34820	4878	34073	5070	21
10	37149	4329	36351	4509	35571	4693	34807	4881	34061	5073	
	37135	4332	36338	4512	35558	4696	34795	4884	34048	5076	20
11	37122	4334	36325	4515	35545	4699	34782	4887	34036	5080	
	37108	4337	36311	4518	35532	4702	34770	4890	34024	5083	19
12	37095	4340	36298	4521	35519	4705	34757	4894	34011	5086	
	37081	4343	36285	4524	35506	4708	34744	4897	33999	5089	18
13	37068	4346	36272	4527	35493	4711	34732	4900	33987	5093	
	37055	4349	36259	4530	35481	4714	34719	4903	33974	5096	17
14	37041	4352	36246	4533	35468	4718	34707	4906	33962	5099	
	37028	4355	36233	4536	35455	4721	34694	4910	33950	5102	16
15	37014	4358	36220	4539	35442	4724	34682	4913	33938	5016	
	37001	4361	36206	4542	35429	4727	34669	4916	33925	5109	15
16	36988	4364	36193	4545	35417	4730	34657	4919	33913	5112	
	36974	4367	36180	4548	35404	4733	34644	4922	33901	5115	14
17	36961	4370	36167	4551	35391	4736	34632	4925	33889	5119	
	36948	4373	36154	4554	35378	4739	34619	4929	33876	5122	13
18	36934	4376	36141	4557	35365	4742	34607	4932	33864	5125	
	36921	4379	36128	4560	35353	4746	34594	4935	33852	5128	12
19	36907	4382	36115	4563	35340	4749	34582	4938	33840	5132	
	36894	4385	36102	4566	35327	4752	34569	4941	33827	5135	11
20	36881	4388	36089	4569	35314	4755	34557	4945	33815	5138	
	36867	4391	36076	4573	35302	4758	34544	4948	33803	5142	10
21	36854	4394	36063	4576	35289	4761	34532	4951	33791	5145	
	36841	4397	36050	4579	35276	4764	34519	4954	33779	5148	9
22	36827	4400	36037	4582	35263	4769	34507	4957	33766	5151	
	36814	4403	36024	4585	35251	4771	34494	4961	33754	5155	8
23	36801	4406	36011	4588	35238	4774	34482	4964	33742	5158	
	36787	4409	35998	4591	35225	4777	34469	4967	33730	5161	7
24	36774	4412	35985	4594	35212	4780	34457	4970	33717	5164	
	36761	4415	35972	4597	35200	4783	34445	4973	33705	5168	6
25	36747	4418	35959	4600	35187	4786	34432	4977	33693	5171	
	36734	4421	35946	4603	35174	4789	34420	4980	33681	5174	5
26	36721	4424	35933	4606	35161	4793	34407	4983	33669	5178	
	36708	4427	35920	4609	35149	4796	34395	4986	33657	5181	4
27	36694	4430	35907	4612	35136	4799	34382	4989	33644	5184	
	36681	4433	35894	4615	35123	4802	34370	4993	33632	5187	3
28	36668	4436	35881	4619	35111	4805	34357	4996	33620	5191	
	36655	4439	35868	4622	35098	4808	34345	4999	33608	5194	2
29	36641	4442	35855	4625	35085	4811	34332	5002	33596	5197	
	36628	4445	35842	4628	35073	4815	34320	5005	33584	5200	1
30	36615	4448	35829	4631	35060	4818	34308	5009	33572	5204	
	36602	4451	35816	4634	35047	4821	34295	5012	33559	5207	0
	A	B	A	B	A	B	A	B	A	B	
	154°30'		154°00'		153°30'		153°00'		152°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	27°30'		28°00'		28°30'		29°00'		29°30'		
	A	B	A	B	A	B	A	B	A	B	
0	33559	5207	32839	5406	32134	5610	31443	5818	30766	6030	30
	33547	5210	32827	5410	32122	5614	31431	5822	30755	6034	
1	33535	5214	32815	5413	32110	5617	31420	5825	30744	6038	29
	33523	5217	32803	5417	32099	5620	31409	5829	30733	6041	
2	33511	5220	32792	5420	32087	5624	31397	5832	30721	6045	28
	33499	5224	32780	5423	32076	5627	31386	5836	30710	6048	
3	33487	5227	32768	5426	32064	5631	31375	5839	30699	6052	27
	33475	5230	32756	5430	32052	5634	31363	5843	30688	6055	
4	33462	5233	32744	5433	32041	5638	31352	5846	30677	6059	26
	33450	5237	32732	5437	32029	5641	31340	5850	30666	6062	
5	33438	5240	32720	5440	32018	5645	31329	5853	30655	6066	25
	33426	5243	32709	5443	32006	5648	31318	5857	30643	6070	
6	33414	5247	32697	5447	31994	5651	31306	5860	30632	6073	24
	33402	5250	32685	5450	31983	5655	31295	5864	30621	6077	
7	33390	5253	32673	5454	31971	5658	31284	5867	30610	6080	23
	33378	5257	32661	5457	31960	5662	31272	5871	30599	6084	
8	33366	5260	32649	5460	31948	5665	31261	5874	30588	6088	22
	33354	5263	32638	5464	31936	5669	31250	5878	30577	6091	
9	33342	5266	32625	5467	31925	5672	31238	5881	30566	6095	21
	33330	5270	32614	5470	31913	5675	31227	5885	30555	6098	
10	33318	5273	32602	5474	31902	5679	31216	5888	30544	6102	20
	33306	5277	32590	5477	31890	5682	31204	5892	30532	6106	
11	33293	5280	32579	5481	31879	5686	31193	5895	30521	6109	19
	33281	5283	32567	5484	31867	5689	31182	5899	30510	6113	
12	33269	5287	32555	5487	31856	5693	31170	5902	30499	6116	18
	33257	5290	32543	5491	31844	5696	31159	5906	30488	6120	
13	33245	5293	32532	5494	31833	5700	31148	5909	30477	6124	17
	33233	5296	32520	5498	31821	5703	31137	5913	30466	6127	
14	33221	5300	32508	5501	31809	5707	31125	5917	30455	6131	16
	33209	5303	32496	5504	31798	5710	31114	5920	30444	6134	
15	33197	5306	32484	5508	31786	5714	31103	5924	30433	6138	15
	33185	5310	32473	5511	31775	5717	31091	5927	30422	6142	
16	33173	5313	32461	5515	31763	5720	31080	5931	30411	6145	14
	33161	5316	32449	5518	31752	5724	31069	5934	30400	6149	
17	33149	5320	32438	5521	31740	5727	31058	5938	30389	6153	13
	33137	5323	32426	5525	31729	5731	31046	5941	30378	6156	
18	33125	5326	32414	5528	31717	5734	31035	5945	30367	6160	12
	33113	5330	32402	5532	31706	5738	31024	5948	30356	6163	
19	33101	5333	32391	5535	31694	5741	31013	5952	30345	6167	11
	33089	5336	32379	5538	31683	5745	31001	5955	30334	6171	
20	33077	5340	32367	5542	31672	5748	30990	5959	30322	6174	10
	33065	5343	32355	5545	31660	5752	30979	5963	30311	6178	
21	33054	5346	32344	5549	31648	5755	30968	5966	30300	6181	9
	33042	5350	32332	5552	31637	5759	30956	5970	30289	6185	
22	33030	5353	32320	5555	31626	5762	30945	5973	30278	6189	8
	33018	5356	32309	5559	31614	5766	30934	5977	30267	6192	
23	33006	5360	32297	5562	31603	5769	30923	5980	30256	6196	7
	32994	5363	32285	5566	31591	5773	30912	5984	30245	6200	
24	32982	5366	32274	5569	31580	5776	30900	5988	30235	6203	6
	32970	5370	32262	5572	31569	5780	30889	5991	30224	6207	
25	32958	5373	32250	5576	31557	5783	30878	5995	30213	6210	5
	32946	5376	32239	5579	31546	5787	30867	5998	30202	6214	
26	32934	5380	32227	5583	31534	5790	30856	6002	30191	6218	4
	32922	5383	32215	5586	31523	5794	30844	6005	30180	6221	
27	32910	5386	32204	5590	31511	5797	30833	6009	30169	6225	3
	32898	5390	32192	5593	31500	5801	30822	6012	30158	6229	
28	32887	5393	32180	5596	31488	5804	30811	6016	30147	6232	2
	32875	5396	32169	5600	31477	5808	30800	6020	30136	6236	
29	32863	5400	32157	5603	31466	5811	30788	6023	30125	6240	1
	32851	5403	32145	5607	31454	5815	30777	6027	30114	6243	
30	32839	5406	32134	5610	31443	5818	30766	6030	30103	6247	0
	A	B	A	B	A	B	A	B	A	B	
	152°00'		151°30'		151°00'		150°30'		150°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	30°00'		30°30'		31°00'		31°30'		32°00'		
	A	B	A	B	A	B	A	B	A	B	
0	30103	.6247	29453	.6468	28816	.6693	28191	.6923	27579	.7158	30
1	30092	.6251	29442	.6472	28806	.6697	28181	.6927	27569	.7162	29
	30081	.6254	29432	.6475	28795	.6701	28171	.6931	27559	.7166	
2	30070	.6258	29421	.6479	28785	.6705	28161	.6935	27549	.7170	28
	30059	.6262	29410	.6483	28774	.6709	28150	.6939	27539	.7174	
3	30048	.6265	29399	.6487	28763	.6712	28140	.6943	27528	.7178	27
	30037	.6269	29389	.6490	28753	.6716	28130	.6947	27518	.7182	
4	30026	.6273	29378	.6494	28743	.6720	28119	.6951	27508	.7186	26
	30016	.6276	29367	.6498	28732	.6724	28109	.6954	27498	.7190	
5	30005	.6280	29357	.6501	28722	.6728	28099	.6958	27488	.7193	25
	29994	.6284	29346	.6505	28711	.6731	28089	.6962	27478	.7197	
6	29983	.6287	29335	.6509	28701	.6735	28078	.6966	27468	.7201	24
	29972	.6291	29325	.6513	28690	.6739	28068	.6970	27458	.7205	
7	29961	.6294	29314	.6516	28680	.6743	28058	.6974	27448	.7209	23
	29950	.6298	29303	.6520	28669	.6747	28047	.6978	27438	.7213	
8	29939	.6302	29293	.6524	28659	.6750	28037	.6982	27428	.7217	22
	29928	.6305	29282	.6528	28648	.6754	28027	.6985	27418	.7221	
9	29917	.6309	29271	.6531	28638	.6758	28017	.6989	27408	.7225	21
	29907	.6313	29261	.6535	28627	.6762	28006	.6993	27398	.7229	
10	29896	.6316	29250	.6539	28617	.6766	27996	.6997	27387	.7233	20
	29885	.6320	29239	.6543	28606	.6770	27986	.7001	27377	.7237	
11	29874	.6324	29229	.6546	28596	.6773	27976	.7005	27367	.7241	19
	29863	.6328	29218	.6550	28586	.6777	27965	.7009	27357	.7245	
12	29852	.6331	29207	.6554	28575	.6781	27955	.7013	27347	.7249	18
	29841	.6335	29197	.6558	28565	.6785	27945	.7017	27337	.7253	
13	29831	.6339	29186	.6561	28554	.6789	27935	.7021	27327	.7257	17
	29820	.6342	29175	.6565	28544	.6793	27925	.7024	27317	.7261	
14	29809	.6346	29165	.6569	28533	.6796	27914	.7028	27307	.7265	16
	29798	.6350	29154	.6573	28523	.6800	27904	.7032	27297	.7269	
15	29787	.6353	29144	.6576	28513	.6804	27894	.7036	27287	.7273	15
	29776	.6357	29133	.6580	28502	.6808	27884	.7040	27277	.7277	
16	29766	.6361	29122	.6584	28492	.6812	27874	.7044	27267	.7281	14
	29755	.6364	29112	.6588	28481	.6815	27863	.7048	27257	.7285	
17	29744	.6368	29101	.6591	28471	.6819	27853	.7052	27247	.7289	13
	29733	.6372	29091	.6595	28461	.6823	27843	.7056	27237	.7293	
18	29722	.6375	29080	.6599	28450	.6827	27833	.7060	27227	.7297	12
	29711	.6379	29069	.6603	28440	.6831	27823	.7064	27217	.7301	
19	29701	.6383	29059	.6606	28429	.6835	27812	.7067	27207	.7305	11
	29690	.6386	29048	.6610	28419	.6839	27802	.7071	27197	.7309	
20	29679	.6390	29038	.6614	28409	.6842	27792	.7075	27187	.7313	10
	29668	.6394	29027	.6618	28398	.6846	27782	.7079	27177	.7317	
21	29657	.6398	29016	.6622	28388	.6850	27772	.7083	27167	.7321	9
	29647	.6401	29006	.6625	28378	.6854	27761	.7087	27157	.7325	
22	29636	.6405	28995	.6629	28367	.6858	27751	.7091	27147	.7329	8
	29625	.6409	28985	.6633	28357	.6862	27741	.7095	27137	.7333	
23	29614	.6412	28974	.6637	28346	.6865	27731	.7099	27127	.7337	7
	29604	.6416	28964	.6640	28336	.6869	27721	.7103	27117	.7341	
24	29593	.6420	28953	.6644	28326	.6873	27711	.7107	27107	.7345	6
	29582	.6423	28942	.6648	28315	.6877	27701	.7111	27098	.7349	
25	29571	.6427	28932	.6652	28305	.6881	27690	.7115	27088	.7353	5
	29560	.6431	28921	.6655	28295	.6885	27680	.7118	27078	.7357	
26	29550	.6435	28911	.6659	28284	.6889	27670	.7122	27068	.7361	4
	29539	.6438	28900	.6663	28274	.6893	27660	.7126	27058	.7365	
27	29528	.6442	28890	.6667	28264	.6896	27650	.7130	27048	.7369	3
	29517	.6446	28879	.6671	28253	.6900	27640	.7134	27038	.7373	
28	29507	.6449	28869	.6674	28243	.6904	27630	.7138	27028	.7377	2
	29496	.6453	28858	.6678	28233	.6908	27619	.7142	27018	.7381	
29	29485	.6457	28848	.6682	28222	.6912	27609	.7146	27008	.7385	1
	29475	.6461	28837	.6686	28212	.6916	27599	.7150	26998	.7389	
30	29464	.6464	28827	.6690	28202	.6920	27589	.7154	26988	.7393	0
	29453	.6468	28816	.6693	28191	.6923	27579	.7158	26978	.7397	
	A	B	A	B	A	B	A	B	A	B	
	149°30'		149°00'		148°30'		148°00'		147°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	32°30'		33°00'		33°30'		34°00'		34°30'		
	A	B	A	B	A	B	A	B	A	B	
0	26978 7397		26389 7641		25811 7889		25244 8143		24687 8401		30
	26968 7401		26379 7645		25801 7893		25235 8147		24678 8405		
1	26958 7405		26370 7649		25792 7898		25225 8151		24669 8409		29
	26949 7409		26360 7653		25782 7902		25216 8155		24660 8414		
2	26939 7413		26350 7657		25773 7906		25206 8160		24650 8418		28
	26929 7417		26340 7661		25763 7910		25197 8164		24641 8422		
3	26919 7421		26331 7665		25754 7914		25188 8168		24632 8427		27
	26909 7425		26321 7670		25744 7919		25178 8172		24623 8431		
4	26899 7429		26311 7674		25735 7923		25169 8177		24614 8435		26
	26889 7433		26302 7678		25725 7927		25160 8181		24605 8440		
5	26879 7437		26292 7682		25718 7931		25150 8185		24595 8444		25
	26869 7441		26282 7686		25706 7935		25141 8189		24586 8448		
6	26860 7445		26273 7690		25697 7940		25132 8194		24577 8453		24
	26850 7449		26263 7694		25687 7944		25122 8198		24568 8457		
7	26840 7453		26253 7698		25678 7948		25113 8202		24559 8461		23
	26830 7458		26244 7702		25668 7952		25104 8207		24550 8466		
8	26820 7462		26234 7707		25659 7956		25094 8211		24540 8470		22
	26810 7466		26224 7711		25649 7961		25085 8215		24531 8475		
9	26800 7470		26214 7715		25640 7965		25076 8219		24522 8479		21
	26790 7474		26205 7719		25630 7969		25066 8224		24513 8483		
10	26781 7478		26195 7723		25621 7973		25057 8228		24504 8488		20
	26771 7482		26185 7727		25611 7977		25048 8232		24495 8492		
11	26761 7486		26176 7731		25602 7982		25038 8237		24486 8496		19
	26751 7490		26166 7736		25592 7986		25029 8241		24477 8501		
12	26741 7494		26157 7740		25583 7990		25020 8245		24467 8505		18
	26731 7498		26147 7744		25573 7994		25011 8249		24458 8510		
13	26722 7502		26137 7748		25564 7998		25001 8254		24449 8514		17
	26712 7506		26128 7752		25554 8003		24992 8258		24440 8518		
14	26702 7510		26118 7756		25545 8007		24983 8262		24431 8523		16
	26692 7514		26108 7760		25536 8011		24973 8267		24422 8527		
15	26682 7518		26099 7764		25526 8015		24964 8271		24413 8531		15
	26672 7522		26089 7769		25517 8020		24955 8275		24404 8536		
16	26663 7526		26079 7773		25507 8024		24946 8280		24395 8540		14
	26653 7531		26070 7777		25498 8028		24936 8284		24385 8545		
17	26643 7535		26060 7781		25488 8032		24927 8288		24376 8549		13
	26633 7539		26051 7785		25479 8037		24918 8292		24367 8553		
18	26623 7543		26041 7789		25469 8041		24909 8297		24358 8558		12
	26614 7547		26031 7793		25460 8045		24899 8301		24349 8562		
19	26604 7551		26022 7798		25451 8049		24890 8305		24340 8567		11
	26594 7555		26012 7802		25441 8053		24881 8310		24331 8571		
20	26584 7559		26002 7806		25432 8058		24872 8314		24322 8575		10
	26574 7563		25993 7810		25422 8062		24862 8318		24313 8580		
21	26565 7567		25983 7814		25413 8066		24853 8323		24304 8584		9
	26555 7571		25974 7818		25403 8070		24844 8327		24295 8589		
22	26545 7575		25964 7823		25394 8075		24835 8331		24286 8593		8
	26535 7579		25954 7827		25385 8079		24825 8336		24276 8597		
23	26526 7584		25945 7831		25375 8083		24816 8340		24267 8602		7
	26516 7588		25935 7835		25366 8087		24807 8344		24258 8606		
24	26506 7592		25926 7839		25356 8091		24798 8349		24249 8611		6
	26496 7596		25916 7843		25347 8096		24788 8353		24240 8615		
25	26486 7600		25907 7848		25338 8100		24779 8357		24231 8619		5
	26477 7604		25897 7852		25328 8104		24770 8362		24222 8624		
26	26467 7608		25887 7856		25319 8108		24761 8366		24213 8628		4
	26457 7612		25878 7860		25309 8113		24752 8370		24204 8633		
27	26447 7616		25868 7864		25300 8117		24742 8375		24195 8637		3
	26438 7620		25859 7868		25291 8121		24733 8379		24186 8641		
28	26428 7625		25849 7873		25281 8125		24724 8383		24177 8646		2
	26418 7629		25840 7877		25272 8130		24715 8388		24168 8650		
29	26409 7633		25830 7881		25263 8134		24706 8392		24159 8655		1
	26399 7637		25821 7885		25253 8138		24696 8396		24150 8659		
30	26389 7641		25811 7889		25244 8143		24687 8401		24141 8663		0
	A	B	A	B	A	B	A	B	A	B	
	147°00'		146°30'		146°00'		145°30'		145°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	35°00'		35°30'		36°00'		36°30'		37°00'		
	A	B	A	B	A	B	A	B	A	B	
0	24141	8663	23605	8931	23078	9204	22561	9482	22054	9765	30
	24132	8668	23596	8936	23069	9209	22553	9487	22045	9770	
1	24123	8672	23587	8940	23061	9213	22544	9492	22037	9775	29
	24114	8677	23578	8945	23052	9218	22536	9496	22029	9779	
2	24105	8681	23569	8949	23043	9223	22527	9501	22020	9784	28
	24096	8686	23560	8954	23035	9227	22519	9505	22012	9789	
3	24087	8690	23551	8958	23026	9232	22510	9510	22003	9794	27
	24078	8694	23543	8963	23017	9236	22501	9515	21995	9798	
4	24069	8699	23534	8967	23009	9241	22493	9520	21987	9803	26
	24060	8703	23525	8972	23000	9246	22484	9524	21978	9808	
5	24051	8708	23516	8976	22991	9250	22476	9529	21970	9813	25
	24042	8712	23507	8981	22983	9255	22467	9534	21962	9818	
6	24033	8717	23498	8986	22974	9259	22459	9538	21953	9822	24
	24024	8721	23490	8990	22965	9264	22450	9543	21945	9827	
7	24015	8726	23481	8995	22957	9269	22442	9548	21937	9832	23
	24006	8730	23472	8999	22948	9273	22433	9552	21928	9837	
8	23997	8734	23463	9004	22939	9278	22425	9557	21920	9841	22
	23988	8739	23454	9008	22931	9282	22416	9562	21912	9846	
9	23979	8743	23446	9013	22922	9287	22408	9566	21903	9851	21
	23970	8748	23437	9017	22913	9292	22399	9571	21895	9856	
10	23961	8752	23428	9022	22905	9296	22391	9576	21887	9861	20
	23952	8757	23419	9026	22896	9301	22382	9581	21878	9865	
11	23943	8761	23410	9031	22887	9305	22374	9585	21870	9870	19
	23934	8766	23402	9035	22879	9310	22366	9590	21862	9875	
12	23925	8770	23393	9040	22870	9315	22357	9595	21853	9880	18
	23916	8775	23384	9044	22862	9319	22349	9599	21845	9885	
13	23907	8779	23375	9049	22853	9324	22340	9604	21837	9889	17
	23898	8783	23366	9054	22844	9329	22332	9609	21828	9894	
14	23889	8788	23358	9058	22836	9333	22323	9614	21820	9899	16
	23880	8792	23349	9063	22827	9338	22315	9618	21812	9904	
15	23871	8797	23340	9067	22818	9342	22306	9623	21803	9909	15
	23863	8801	23331	9072	22810	9347	22298	9628	21795	9913	
16	23854	8806	23323	9076	22801	9352	22289	9632	21787	9918	14
	23845	8810	23314	9081	22793	9356	22281	9637	21778	9923	
17	23836	8815	23305	9085	22784	9361	22272	9642	21770	9928	13
	23827	8819	23296	9090	22775	9366	22264	9647	21762	9933	
18	23818	8824	23288	9094	22767	9370	22256	9651	21754	9937	12
	23809	8828	23279	9099	22758	9375	22247	9656	21745	9942	
19	23800	8833	23270	9104	22750	9380	22239	9661	21737	9947	11
	23791	8837	23261	9108	22741	9384	22230	9665	21729	9952	
20	23782	8842	23252	9113	22732	9389	22222	9670	21720	9957	10
	23773	8846	23244	9117	22724	9394	22213	9675	21712	9962	
21	23764	8850	23235	9122	22715	9398	22205	9680	21704	9966	9
	23755	8855	23226	9126	22707	9403	22197	9684	21696	9971	
22	23747	8859	23218	9131	22698	9407	22188	9689	21687	9976	8
	23738	8864	23209	9136	22690	9412	22180	9694	21679	9981	
23	23729	8868	23200	9140	22681	9417	22171	9699	21671	9986	7
	23720	8873	23191	9145	22672	9421	22168	9703	21662	9990	
24	23711	8877	23183	9149	22664	9426	22154	9708	21654	9995	6
	23702	8882	23174	9154	22655	9431	22146	9713	21646	10000	
25	23693	8886	23165	9158	22647	9435	22138	9718	21638	10005	5
	23684	8891	23156	9163	22638	9440	22129	9722	21629	10010	
26	23675	8895	23148	9168	22630	9445	22121	9727	21621	10015	4
	23667	8900	23139	9172	22621	9449	22112	9732	21613	10019	
27	23658	8904	23130	9177	22612	9454	22104	9737	21605	10024	3
	23649	8909	23122	9181	22604	9459	22096	9741	21596	10029	
28	23640	8913	23113	9186	22595	9463	22087	9746	21588	10034	2
	23631	8918	23104	9190	22587	9468	22079	9751	21580	10039	
29	23622	8922	23095	9195	22578	9473	22070	9756	21572	10044	1
	23613	8927	23087	9200	22570	9477	22062	9760	21563	10049	
30	23605	8931	23078	9204	22561	9482	22054	9765	21555	10053	0
	A	B	A	B	A	B	A	B	A	B	
	144°30'		144°00'		143°30'		143°00'		142°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	37°30'		38°00'		38°30'		39°00'		39°30'		
	A	B	A	B	A	B	A	B	A	B	
0	21555 ... 10053		21066 ... 10347		20585 ... 10646		20113 ... 10950		19649 ... 11259		30
	21547 ... 10058		21058 ... 10352		20577 ... 10851		20105 ... 10955		19841 ... 11265		
1	21539 ... 10063		21050 ... 10357		20569 ... 10656		20097 ... 10960		19634 ... 11270		29
	21531 ... 10068		21042 ... 10362		20561 ... 10661		20089 ... 10965		19628 ... 11275		
2	21522 ... 10073		21033 ... 10367		20553 ... 10666		20082 ... 10970		19818 ... 11280		28
	21514 ... 10078		21025 ... 10372		20545 ... 10671		20074 ... 10975		19811 ... 11285		
3	21506 ... 10082		21017 ... 10376		20537 ... 10676		20066 ... 10980		19803 ... 11291		27
	21498 ... 10087		21009 ... 10381		20529 ... 10681		20058 ... 10986		19595 ... 11298		
4	21489 ... 10092		21001 ... 10386		20522 ... 10686		20050 ... 10991		19588 ... 11301		28
	21481 ... 10097		20993 ... 10391		20514 ... 10691		20043 ... 10996		19580 ... 11306		
5	21473 ... 10102		20985 ... 10396		20506 ... 10696		20035 ... 11001		19572 ... 11311		25
	21465 ... 10107		20977 ... 10401		20498 ... 10701		20027 ... 11006		19565 ... 11317		
6	21457 ... 10112		20969 ... 10406		20490 ... 10706		20019 ... 11011		19557 ... 11322		24
	21448 ... 10116		20961 ... 10411		20482 ... 10711		20012 ... 11016		19549 ... 11327		
7	21440 ... 10121		20953 ... 10416		20474 ... 10716		20004 ... 11021		19541 ... 11332		23
	21432 ... 10126		20945 ... 10421		20466 ... 10721		19996 ... 11027		19534 ... 11338		
8	21424 ... 10131		20937 ... 10426		20458 ... 10726		19988 ... 11032		19527 ... 11343		22
	21416 ... 10136		20929 ... 10431		20450 ... 10731		19980 ... 11037		19519 ... 11348		
9	21407 ... 10141		20921 ... 10436		20442 ... 10736		19973 ... 11042		19511 ... 11353		21
	21399 ... 10146		20913 ... 10441		20435 ... 10741		19965 ... 11047		19504 ... 11359		
10	21391 ... 10151		20905 ... 10446		20427 ... 10746		19957 ... 11052		19498 ... 11364		20
	21383 ... 10155		20897 ... 10451		20419 ... 10751		19949 ... 11057		19488 ... 11369		
11	21375 ... 10160		20888 ... 10456		20411 ... 10756		19942 ... 11063		19481 ... 11374		19
	21367 ... 10165		20880 ... 10461		20403 ... 10761		19934 ... 11068		19473 ... 11380		
12	21358 ... 10170		20872 ... 10466		20395 ... 10767		19926 ... 11073		19466 ... 11385		18
	21350 ... 10175		20864 ... 10471		20387 ... 10772		19919 ... 11078		19458 ... 11390		
13	21342 ... 10180		20856 ... 10476		20379 ... 10777		19911 ... 11083		19450 ... 11395		17
	21334 ... 10185		20848 ... 10481		20371 ... 10782		19903 ... 11088		19443 ... 11400		
14	21326 ... 10190		20840 ... 10486		20364 ... 10787		19895 ... 11094		19435 ... 11406		16
	21318 ... 10195		20832 ... 10491		20356 ... 10792		19888 ... 11099		19428 ... 11411		
15	21309 ... 10199		20824 ... 10496		20348 ... 10797		19880 ... 11104		19420 ... 11416		15
	21301 ... 10204		20816 ... 10500		20340 ... 10802		19872 ... 11109		19412 ... 11422		
16	21293 ... 10209		20808 ... 10505		20332 ... 10807		19864 ... 11114		19405 ... 11427		14
	21285 ... 10214		20800 ... 10510		20324 ... 10812		19857 ... 11119		19397 ... 11432		
17	21277 ... 10219		20792 ... 10515		20316 ... 10817		19849 ... 11124		19390 ... 11437		13
	21269 ... 10224		20784 ... 10520		20309 ... 10822		19841 ... 11130		19382 ... 11443		
18	21260 ... 10229		20776 ... 10525		20301 ... 10827		19834 ... 11135		19375 ... 11448		12
	21252 ... 10234		20768 ... 10530		20293 ... 10832		19826 ... 11140		19367 ... 11453		
19	21244 ... 10239		20760 ... 10535		20285 ... 10838		19818 ... 11145		19359 ... 11458		11
	21236 ... 10243		20752 ... 10540		20277 ... 10843		19810 ... 11150		19352 ... 11464		
20	21228 ... 10248		20744 ... 10545		20269 ... 10848		19803 ... 11156		19344 ... 11469		10
	21220 ... 10253		20736 ... 10550		20261 ... 10853		19795 ... 11161		19337 ... 11474		
21	21212 ... 10258		20728 ... 10555		20254 ... 10858		19787 ... 11166		19329 ... 11479		9
	21204 ... 10263		20720 ... 10560		20246 ... 10863		19779 ... 11171		19321 ... 11485		
22	21195 ... 10268		20712 ... 10565		20238 ... 10868		19772 ... 11176		19314 ... 11490		8
	21187 ... 10273		20704 ... 10570		20230 ... 10873		19764 ... 11181		19306 ... 11495		
23	21179 ... 10278		20696 ... 10575		20222 ... 10878		19756 ... 11187		19299 ... 11501		7
	21171 ... 10283		20688 ... 10580		20214 ... 10883		19749 ... 11192		19291 ... 11506		
24	21163 ... 10288		20680 ... 10585		20207 ... 10888		19741 ... 11197		19284 ... 11511		6
	21155 ... 10293		20672 ... 10590		20199 ... 10894		19733 ... 11202		19276 ... 11516		
25	21147 ... 10298		20665 ... 10595		20191 ... 10899		19726 ... 11207		19269 ... 11522		5
	21139 ... 10302		20657 ... 10600		20183 ... 10904		19718 ... 11213		19261 ... 11527		
26	21131 ... 10307		20649 ... 10605		20175 ... 10909		19710 ... 11218		19253 ... 11532		4
	21122 ... 10312		20641 ... 10610		20167 ... 10914		19703 ... 11223		19246 ... 11537		
27	21114 ... 10317		20633 ... 10615		20160 ... 10919		19695 ... 11228		19238 ... 11543		3
	21106 ... 10322		20625 ... 10620		20152 ... 10924		19687 ... 11233		19231 ... 11548		
28	21098 ... 10327		20617 ... 10625		20144 ... 10929		19680 ... 11239		19223 ... 11553		2
	21090 ... 10332		20609 ... 10630		20136 ... 10934		19672 ... 11244		19216 ... 11559		
29	21082 ... 10337		20601 ... 10635		20128 ... 10939		19664 ... 11249		19208 ... 11564		1
	21074 ... 10342		20593 ... 10640		20121 ... 10945		19657 ... 11254		19201 ... 11569		
30	21066 ... 10347		20585 ... 10646		20113 ... 10950		19649 ... 11259		19193 ... 11575		0
	A	B	A	B	A	B	A	B	A	B	
	142°00'		141°30'		141°00'		140°30'		140°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	40°00'		40°30'		41°00'		41°30'		42°00'		
	A	B	A	B	A	B	A	B	A	B	
0	19193 ... 11575		18746 ... 11895		18306 ... 12222		17873 ... 12554		17449 ... 12893		30
	19186 ... 11580		18738 ... 11901		18298 ... 12228		17866 ... 12560		17442 ... 12898		
1	19178 ... 11585		18731 ... 11906		18291 ... 12233		17859 ... 12566		17435 ... 12904		29
	19171 ... 11590		18723 ... 11912		18284 ... 12238		17852 ... 12571		17428 ... 12910		
2	19163 ... 11596		18716 ... 11917		18277 ... 12244		17845 ... 12577		17421 ... 12915		28
	19156 ... 11601		18709 ... 11922		18269 ... 12249		17838 ... 12582		17414 ... 12921		
3	19148 ... 11606		18701 ... 11928		18262 ... 12255		17831 ... 12588		17407 ... 12927		27
	19141 ... 11612		18694 ... 11933		18255 ... 12260		17824 ... 12593		17400 ... 12932		
4	19133 ... 11617		18686 ... 11939		18248 ... 12266		17816 ... 12599		17393 ... 12938		26
	19126 ... 11622		18679 ... 11944		18240 ... 12271		17809 ... 12605		17386 ... 12944		
5	19118 ... 11628		18672 ... 11949		18233 ... 12277		17802 ... 12610		17379 ... 12950		25
	19111 ... 11633		18664 ... 11955		18226 ... 12282		17795 ... 12616		17372 ... 12955		
6	19103 ... 11638		18657 ... 11960		18219 ... 12288		17788 ... 12622		17365 ... 12961		24
	19096 ... 11644		18650 ... 11966		18211 ... 12293		17781 ... 12627		17358 ... 12967		
7	19088 ... 11649		18642 ... 11971		18204 ... 12299		17774 ... 12633		17351 ... 12972		23
	19081 ... 11654		18635 ... 11977		18197 ... 12305		17767 ... 12638		17344 ... 12978		
8	19073 ... 11660		18627 ... 11982		18190 ... 12310		17760 ... 12644		17337 ... 12984		22
	19066 ... 11665		18620 ... 11987		18182 ... 12316		17752 ... 12650		17330 ... 12990		
9	19058 ... 11670		18613 ... 11993		18175 ... 12321		17745 ... 12655		17323 ... 12995		21
	19051 ... 11676		18605 ... 11998		18168 ... 12327		17738 ... 12661		17316 ... 13001		
10	19043 ... 11681		18598 ... 12004		18161 ... 12332		17731 ... 12667		17309 ... 13007		20
	19036 ... 11686		18591 ... 12009		18154 ... 12338		17724 ... 12672		17302 ... 13012		
11	19028 ... 11692		18583 ... 12014		18146 ... 12343		17717 ... 12678		17295 ... 13018		19
	19021 ... 11697		18576 ... 12020		18139 ... 12349		17710 ... 12683		17288 ... 13024		
12	19013 ... 11702		18569 ... 12025		18132 ... 12354		17703 ... 12689		17281 ... 13030		18
	19006 ... 11708		18561 ... 12031		18125 ... 12360		17696 ... 12695		17274 ... 13035		
13	18998 ... 11713		18554 ... 12036		18117 ... 12365		17689 ... 12700		17267 ... 13041		17
	18991 ... 11718		18547 ... 12042		18110 ... 12371		17681 ... 12706		17260 ... 13047		
14	18983 ... 11724		18539 ... 12047		18103 ... 12376		17674 ... 12711		17253 ... 13053		16
	18976 ... 11729		18532 ... 12053		18096 ... 12382		17667 ... 12717		17246 ... 13058		
15	18968 ... 11734		18525 ... 12058		18089 ... 12387		17660 ... 12723		17239 ... 13064		15
	18961 ... 11740		18517 ... 12063		18081 ... 12393		17653 ... 12728		17232 ... 13070		
16	18953 ... 11745		18510 ... 12069		18074 ... 12398		17646 ... 12734		17225 ... 13075		14
	18946 ... 11750		18503 ... 12074		18067 ... 12404		17639 ... 12740		17218 ... 13081		
17	18939 ... 11756		18495 ... 12080		18060 ... 12410		17632 ... 12745		17212 ... 13087		13
	18931 ... 11761		18488 ... 12085		18053 ... 12415		17625 ... 12751		17205 ... 13093		
18	18924 ... 11766		18481 ... 12091		18045 ... 12421		17618 ... 12757		17198 ... 13098		12
	18916 ... 11772		18473 ... 12096		18038 ... 12426		17611 ... 12762		17191 ... 13104		
19	18909 ... 11777		18466 ... 12102		18031 ... 12432		17604 ... 12768		17184 ... 13110		11
	18901 ... 11782		18459 ... 12107		18024 ... 12437		17597 ... 12774		17177 ... 13116		
20	18894 ... 11788		18451 ... 12112		18017 ... 12443		17590 ... 12779		17170 ... 13121		10
	18886 ... 11793		18444 ... 12118		18010 ... 12448		17583 ... 12785		17163 ... 13127		
21	18879 ... 11799		18437 ... 12123		18002 ... 12454		17575 ... 12790		17156 ... 13133		9
	18872 ... 11804		18429 ... 12129		17995 ... 12460		17568 ... 12796		17149 ... 13139		
22	18864 ... 11809		18422 ... 12134		17988 ... 12465		17561 ... 12802		17142 ... 13144		8
	18857 ... 11815		18415 ... 12140		17981 ... 12471		17554 ... 12807		17135 ... 13150		
23	18849 ... 11820		18408 ... 12145		17974 ... 12476		17547 ... 12813		17128 ... 13156		7
	18842 ... 11825		18400 ... 12151		17966 ... 12482		17540 ... 12819		17121 ... 13162		
24	18834 ... 11831		18393 ... 12156		17959 ... 12487		17533 ... 12824		17114 ... 13168		6
	18827 ... 11836		18386 ... 12162		17952 ... 12493		17526 ... 12830		17108 ... 13173		
25	18820 ... 11842		18378 ... 12167		17945 ... 12499		17519 ... 12836		17101 ... 13179		5
	18812 ... 11847		18371 ... 12173		17938 ... 12504		17512 ... 12841		17094 ... 13185		
26	18805 ... 11852		18364 ... 12178		17931 ... 12510		17505 ... 12847		17087 ... 13191		4
	18797 ... 11858		18357 ... 12184		17924 ... 12515		17498 ... 12853		17080 ... 13196		
27	18790 ... 11863		18349 ... 12189		17916 ... 12521		17491 ... 12859		17073 ... 13202		3
	18783 ... 11868		18342 ... 12195		17909 ... 12526		17484 ... 12864		17066 ... 13208		
28	18775 ... 11874		18335 ... 12200		17902 ... 12532		17477 ... 12870		17059 ... 13214		2
	18768 ... 11879		18327 ... 12205		17895 ... 12538		17470 ... 12876		17052 ... 13220		
29	18760 ... 11885		18320 ... 12211		17888 ... 12543		17463 ... 12881		17046 ... 13225		1
	18753 ... 11890		18313 ... 12216		17881 ... 12549		17456 ... 12887		17039 ... 13231		
30	18746 ... 11895		18306 ... 12222		17873 ... 12554		17449 ... 12893		17032 ... 13237		0
	A	B	A	B	A	B	A	B	A	B	
	139°30'		139°00'		138°30'		138°00'		137°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	42°30'		43°00'		43°30'		44°00'		44°30'		
	A	B	A	B	A	B	A	B	A	B	
0	17032 ... 13237		16622 ... 13587		16219 ... 13944		15823 ... 14307		15434 ... 14676		30
	17025 ... 13243		16615 ... 13593		16212 ... 13950		15816 ... 14313		15427 ... 14682		
1	17018 ... 13248		16608 ... 13599		16205 ... 13956		15810 ... 14319		15421 ... 14688		29
	17011 ... 13254		16601 ... 13605		16199 ... 13962		15803 ... 14325		15414 ... 14694		
2	17004 ... 13260		16595 ... 13811		16192 ... 13968		15797 ... 14331		15408 ... 14701		28
	16997 ... 13266		16588 ... 13617		16186 ... 13974		15790 ... 14337		15402 ... 14707		
3	16990 ... 13272		16581 ... 13623		16179 ... 13980		15784 ... 14343		15395 ... 14713		27
	16983 ... 13277		16574 ... 13628		16172 ... 13986		15777 ... 14349		15389 ... 14719		
4	16977 ... 13283		16567 ... 13634		16166 ... 13992		15771 ... 14355		15382 ... 14726		26
	16970 ... 13289		16561 ... 13640		16159 ... 13998		15764 ... 14362		15376 ... 14732		
5	16963 ... 13295		16554 ... 13646		16152 ... 14004		15758 ... 14368		15370 ... 14738		25
	16956 ... 13301		16547 ... 13652		16146 ... 14010		15751 ... 14374		15363 ... 14744		
6	16949 ... 13306		16540 ... 13658		16139 ... 14018		15744 ... 14380		15357 ... 14750		24
	16942 ... 13312		16534 ... 13664		16132 ... 14022		15738 ... 14386		15350 ... 14757		
7	16935 ... 13318		16527 ... 13670		16126 ... 14028		15731 ... 14392		15344 ... 14763		23
	16928 ... 13324		16520 ... 13676		16119 ... 14034		15725 ... 14398		15338 ... 14769		
8	16922 ... 13330		16513 ... 13682		16112 ... 14040		15718 ... 14404		15331 ... 14775		22
	16915 ... 13336		16507 ... 13688		16106 ... 14046		15712 ... 14411		15325 ... 14782		
9	16908 ... 13341		16500 ... 13694		16099 ... 14052		15705 ... 14417		15318 ... 14788		21
	16901 ... 13347		16493 ... 13700		16093 ... 14058		15699 ... 14423		15312 ... 14794		
10	16894 ... 13353		16487 ... 13705		16086 ... 14064		15692 ... 14429		15306 ... 14800		20
	16887 ... 13359		16480 ... 13711		16079 ... 14070		15686 ... 14435		15299 ... 14807		
11	16880 ... 13365		16473 ... 13717		16073 ... 14078		15679 ... 14441		15293 ... 14813		19
	16874 ... 13370		16466 ... 13723		16066 ... 14082		15673 ... 14447		15286 ... 14819		
12	16867 ... 13376		16460 ... 13729		16060 ... 14088		15666 ... 14453		15280 ... 14825		18
	16860 ... 13382		16453 ... 13735		16053 ... 14094		15660 ... 14460		15274 ... 14831		
13	16853 ... 13388		16446 ... 13741		16046 ... 14100		15653 ... 14466		15267 ... 14838		17
	16846 ... 13394		16439 ... 13747		16040 ... 14106		15647 ... 14472		15261 ... 14844		
14	16839 ... 13400		16433 ... 13753		16033 ... 14112		15640 ... 14478		15255 ... 14850		16
	16833 ... 13405		16426 ... 13759		16027 ... 14118		15634 ... 14484		15248 ... 14857		
15	16826 ... 13411		16419 ... 13765		16020 ... 14124		15627 ... 14490		15242 ... 14863		15
	16819 ... 13417		16413 ... 13771		16013 ... 14130		15621 ... 14496		15235 ... 14869		
16	16812 ... 13423		16406 ... 13777		16007 ... 14136		15614 ... 14503		15229 ... 14875		14
	16805 ... 13429		16399 ... 13783		16000 ... 14142		15608 ... 14509		15223 ... 14882		
17	16798 ... 13435		16392 ... 13789		15994 ... 14149		15602 ... 14515		15216 ... 14888		13
	16792 ... 13440		16386 ... 13794		15987 ... 14155		15595 ... 14521		15210 ... 14894		
18	16785 ... 13446		16379 ... 13800		15980 ... 14161		15589 ... 14527		15204 ... 14900		12
	16778 ... 13452		16372 ... 13806		15974 ... 14167		15582 ... 14533		15197 ... 14907		
19	16771 ... 13458		16366 ... 13812		15967 ... 14173		15576 ... 14540		15191 ... 14913		11
	16764 ... 13464		16359 ... 13818		15961 ... 14179		15569 ... 14546		15184 ... 14919		
20	16757 ... 13470		16352 ... 13824		15954 ... 14185		15563 ... 14552		15178 ... 14925		10
	16751 ... 13476		16346 ... 13830		15947 ... 14191		15556 ... 14558		15172 ... 14932		
21	16744 ... 13481		16339 ... 13836		15941 ... 14197		15550 ... 14564		15165 ... 14938		9
	16737 ... 13487		16332 ... 13842		15934 ... 14203		15543 ... 14570		15159 ... 14944		
22	16730 ... 13493		16325 ... 13848		15928 ... 14209		15537 ... 14577		15153 ... 14951		8
	16723 ... 13499		16319 ... 13854		15921 ... 14215		15530 ... 14583		15146 ... 14957		
23	16717 ... 13505		16312 ... 13860		15915 ... 14221		15524 ... 14589		15140 ... 14963		7
	16710 ... 13511		16305 ... 13866		15908 ... 14227		15517 ... 14595		15134 ... 14969		
24	16703 ... 13517		16299 ... 13872		15901 ... 14233		15511 ... 14601		15127 ... 14976		6
	16696 ... 13523		16292 ... 13878		15895 ... 14240		15505 ... 14608		15121 ... 14982		
25	16689 ... 13528		16285 ... 13884		15888 ... 14246		15498 ... 14614		15115 ... 14988		5
	16683 ... 13534		16279 ... 13890		15882 ... 14252		15492 ... 14620		15108 ... 14995		
26	16676 ... 13540		16272 ... 13896		15875 ... 14258		15485 ... 14626		15102 ... 15001		4
	16669 ... 13546		16265 ... 13902		15869 ... 14264		15479 ... 14632		15096 ... 15007		
27	16662 ... 13552		16259 ... 13908		15862 ... 14270		15472 ... 14639		15089 ... 15014		3
	16656 ... 13558		16252 ... 13914		15856 ... 14276		15466 ... 14645		15083 ... 15020		
28	16649 ... 13564		16245 ... 13920		15849 ... 14282		15459 ... 14651		15077 ... 15026		2
	16642 ... 13570		16239 ... 13926		15842 ... 14288		15453 ... 14657		15070 ... 15033		
29	16635 ... 13575		16232 ... 13932		15836 ... 14294		15447 ... 14663		15064 ... 15039		1
	16628 ... 13581		16225 ... 13938		15829 ... 14300		15440 ... 14670		15058 ... 15045		
30	16622 ... 13587		16219 ... 13944		15823 ... 14307		15434 ... 14676		15051 ... 15051		0
	A	B	A	B	A	B	A	B	A	B	
	137°00'		136°30'		136°00'		135°30'		135°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	45°00'		45°30'		46°00'		46°30'		47°00'		
	A	B	A	B	A	B	A	B	A	B	
0	15051 ... 15051		14676 ... 15434		14307 ... 15823		13944 ... 16219		13587 ... 16622		30
	15045 ... 15058		14670 ... 15440		14300 ... 15829		13938 ... 16225		13581 ... 16628		
1	15039 ... 15064		14663 ... 15447		14294 ... 15836		13932 ... 16232		13575 ... 16635		29
	15033 ... 15070		14657 ... 15453		14288 ... 15842		13926 ... 16239		13570 ... 16642		
2	15026 ... 15077		14651 ... 15459		14282 ... 15849		13920 ... 16245		13564 ... 16649		28
	15020 ... 15083		14645 ... 15466		14276 ... 15856		13914 ... 16252		13558 ... 16656		
3	15014 ... 15089		14639 ... 15472		14270 ... 15862		13908 ... 16259		13552 ... 16662		27
	15007 ... 15096		14632 ... 15479		14264 ... 15869		13902 ... 16265		13546 ... 16669		
4	15001 ... 15102		14626 ... 15485		14258 ... 15875		13896 ... 16272		13540 ... 16676		26
	14995 ... 15108		14620 ... 15492		14252 ... 15882		13890 ... 16279		13534 ... 16683		
5	14988 ... 15115		14614 ... 15498		14246 ... 15888		13884 ... 16285		13528 ... 16689		25
	14982 ... 15121		14608 ... 15505		14240 ... 15895		13878 ... 16292		13523 ... 16696		
6	14976 ... 15127		14601 ... 15511		14233 ... 15901		13872 ... 16299		13517 ... 16703		24
	14969 ... 15134		14595 ... 15517		14227 ... 15908		13866 ... 16305		13511 ... 16710		
7	14963 ... 15140		14589 ... 15524		14221 ... 15915		13860 ... 16312		13505 ... 16717		23
	14957 ... 15146		14583 ... 15530		14215 ... 15921		13854 ... 16319		13499 ... 16723		
8	14951 ... 15153		14577 ... 15537		14209 ... 15928		13848 ... 16325		13493 ... 16730		22
	14944 ... 15159		14570 ... 15543		14203 ... 15934		13842 ... 16332		13487 ... 16737		
9	14938 ... 15165		14564 ... 15550		14197 ... 15941		13836 ... 16339		13481 ... 16744		21
	14932 ... 15172		14558 ... 15556		14191 ... 15947		13830 ... 16346		13476 ... 16751		
10	14925 ... 15178		14552 ... 15563		14185 ... 15954		13824 ... 16352		13470 ... 16757		20
	14919 ... 15184		14546 ... 15569		14179 ... 15961		13818 ... 16359		13464 ... 16764		
11	14913 ... 15191		14540 ... 15576		14173 ... 15967		13812 ... 16366		13458 ... 16771		19
	14907 ... 15197		14533 ... 15582		14167 ... 15974		13806 ... 16372		13452 ... 16778		
12	14900 ... 15204		14527 ... 15589		14161 ... 15980		13800 ... 16379		13446 ... 16785		18
	14894 ... 15210		14521 ... 15595		14155 ... 15987		13794 ... 16386		13440 ... 16792		
13	14888 ... 15216		14515 ... 15602		14149 ... 15994		13788 ... 16392		13435 ... 16798		17
	14882 ... 15223		14509 ... 15608		14142 ... 16000		13783 ... 16399		13429 ... 16805		
14	14875 ... 15229		14503 ... 15614		14136 ... 16007		13777 ... 16406		13423 ... 16812		16
	14869 ... 15235		14496 ... 15621		14130 ... 16013		13771 ... 16413		13417 ... 16819		
15	14863 ... 15242		14490 ... 15627		14124 ... 16020		13765 ... 16419		13411 ... 16826		15
	14857 ... 15248		14484 ... 15634		14118 ... 16027		13759 ... 16426		13405 ... 16833		
16	14850 ... 15255		14478 ... 15640		14112 ... 16033		13753 ... 16433		13400 ... 16839		14
	14844 ... 15261		14472 ... 15647		14106 ... 16040		13747 ... 16439		13394 ... 16846		
17	14838 ... 15267		14466 ... 15653		14100 ... 16046		13741 ... 16446		13388 ... 16853		13
	14831 ... 15274		14460 ... 15660		14094 ... 16053		13735 ... 16453		13382 ... 16860		
18	14825 ... 15280		14453 ... 15666		14088 ... 16060		13729 ... 16460		13376 ... 16867		12
	14819 ... 15286		14447 ... 15673		14082 ... 16066		13723 ... 16466		13370 ... 16874		
19	14813 ... 15293		14441 ... 15679		14076 ... 16073		13717 ... 16473		13365 ... 16880		11
	14807 ... 15299		14435 ... 15686		14070 ... 16079		13711 ... 16480		13359 ... 16887		
20	14800 ... 15306		14429 ... 15692		14064 ... 16086		13705 ... 16487		13353 ... 16894		10
	14794 ... 15312		14423 ... 15699		14058 ... 16093		13699 ... 16493		13347 ... 16901		
21	14788 ... 15318		14417 ... 15705		14052 ... 16099		13694 ... 16500		13341 ... 16908		9
	14782 ... 15325		14411 ... 15712		14046 ... 16105		13688 ... 16507		13336 ... 16915		
22	14775 ... 15331		14404 ... 15718		14040 ... 16112		13682 ... 16513		13330 ... 16922		8
	14769 ... 15338		14398 ... 15725		14034 ... 16119		13676 ... 16520		13324 ... 16928		
23	14763 ... 15344		14392 ... 15731		14028 ... 16126		13670 ... 16527		13318 ... 16935		7
	14757 ... 15350		14386 ... 15738		14022 ... 16132		13664 ... 16534		13312 ... 16942		
24	14750 ... 15357		14380 ... 15744		14016 ... 16139		13658 ... 16540		13306 ... 16949		6
	14744 ... 15363		14374 ... 15751		14010 ... 16146		13652 ... 16547		13301 ... 16956		
25	14738 ... 15370		14368 ... 15758		14004 ... 16152		13646 ... 16554		13295 ... 16963		5
	14732 ... 15376		14362 ... 15764		13998 ... 16159		13640 ... 16561		13289 ... 16970		
26	14725 ... 15382		14355 ... 15771		13992 ... 16166		13634 ... 16567		13283 ... 16977		4
	14719 ... 15389		14349 ... 15777		13986 ... 16172		13628 ... 16574		13277 ... 16983		
27	14713 ... 15395		14343 ... 15784		13980 ... 16179		13623 ... 16581		13272 ... 16990		3
	14707 ... 15402		14337 ... 15790		13974 ... 16185		13617 ... 16588		13266 ... 16997		
28	14701 ... 15408		14331 ... 15797		13968 ... 16192		13611 ... 16595		13260 ... 17004		2
	14694 ... 15414		14325 ... 15803		13962 ... 16199		13605 ... 16601		13254 ... 17011		
29	14688 ... 15421		14319 ... 15810		13956 ... 16205		13599 ... 16608		13248 ... 17018		1
	14682 ... 15427		14313 ... 15816		13950 ... 16212		13593 ... 16615		13243 ... 17025		
30	14676 ... 15434		14307 ... 15823		13944 ... 16219		13587 ... 16622		13237 ... 17032		0
	A	B	A	B	A	B	A	B	A	B	
	134°30'		134°00'		133°30'		133°00'		132°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	47°30'		48°00'		48°30'		49°00'		49°30'		
	A	B	A	B	A	B	A	B	A	B	
0	13237 ... 17032		12893 ... 17449		12554 ... 17873		12222 ... 18306		11895 ... 18746		30
	13231 ... 17039		12887 ... 17456		12549 ... 17881		12216 ... 18313		11890 ... 18753		
1	13225 ... 17045		12881 ... 17463		12543 ... 17888		12211 ... 18320		11885 ... 18760		29
	13220 ... 17052		12876 ... 17470		12538 ... 17895		12205 ... 18327		11879 ... 18768		
2	13214 ... 17059		12870 ... 17477		12532 ... 17902		12200 ... 18335		11874 ... 18775		28
	13208 ... 17066		12864 ... 17484		12526 ... 17909		12195 ... 18342		11868 ... 18783		
3	13202 ... 17073		12859 ... 17491		12521 ... 17916		12189 ... 18349		11863 ... 18790		27
	13196 ... 17080		12853 ... 17498		12515 ... 17924		12184 ... 18357		11858 ... 18797		
4	13191 ... 17087		12847 ... 17505		12510 ... 17931		12178 ... 18364		11852 ... 18805		26
	13185 ... 17094		12841 ... 17512		12504 ... 17938		12173 ... 18371		11847 ... 18812		
5	13179 ... 17101		12836 ... 17519		12499 ... 17945		12167 ... 18378		11842 ... 18820		25
	13173 ... 17108		12830 ... 17526		12493 ... 17952		12162 ... 18386		11836 ... 18827		
6	13168 ... 17114		12824 ... 17533		12487 ... 17959		12156 ... 18393		11831 ... 18834		24
	13162 ... 17121		12819 ... 17540		12482 ... 17966		12151 ... 18400		11825 ... 18842		
7	13156 ... 17128		12813 ... 17547		12476 ... 17974		12145 ... 18408		11820 ... 18849		23
	13150 ... 17135		12807 ... 17554		12471 ... 17981		12140 ... 18415		11815 ... 18857		
8	13144 ... 17142		12802 ... 17561		12465 ... 17988		12134 ... 18422		11809 ... 18864		22
	13139 ... 17149		12796 ... 17568		12460 ... 17995		12129 ... 18429		11804 ... 18872		
9	13133 ... 17156		12790 ... 17576		12454 ... 18002		12123 ... 18437		11799 ... 18879		21
	13127 ... 17163		12785 ... 17583		12448 ... 18010		12118 ... 18444		11793 ... 18886		
10	13121 ... 17170		12779 ... 17590		12443 ... 18017		12112 ... 18451		11788 ... 18894		20
	13116 ... 17177		12774 ... 17597		12437 ... 18024		12107 ... 18459		11782 ... 18901		
11	13110 ... 17184		12768 ... 17604		12432 ... 18031		12102 ... 18466		11777 ... 18909		19
	13104 ... 17191		12762 ... 17611		12426 ... 18038		12096 ... 18473		11772 ... 18916		
12	13098 ... 17198		12757 ... 17618		12421 ... 18045		12091 ... 18481		11766 ... 18924		18
	13093 ... 17205		12751 ... 17625		12415 ... 18053		12085 ... 18488		11761 ... 18931		
13	13087 ... 17212		12745 ... 17632		12410 ... 18060		12080 ... 18495		11756 ... 18939		17
	13081 ... 17218		12740 ... 17639		12404 ... 18067		12074 ... 18503		11750 ... 18946		
14	13075 ... 17225		12734 ... 17646		12398 ... 18074		12069 ... 18510		11745 ... 18953		16
	13070 ... 17232		12728 ... 17653		12393 ... 18081		12063 ... 18517		11740 ... 18961		
15	13064 ... 17239		12723 ... 17660		12387 ... 18089		12058 ... 18525		11734 ... 18968		15
	13058 ... 17246		12717 ... 17667		12382 ... 18096		12053 ... 18532		11729 ... 18976		
16	13053 ... 17253		12711 ... 17674		12376 ... 18103		12047 ... 18539		11724 ... 18983		14
	13047 ... 17260		12706 ... 17681		12371 ... 18110		12042 ... 18547		11718 ... 18991		
17	13041 ... 17267		12700 ... 17689		12365 ... 18117		12036 ... 18554		11713 ... 18998		13
	13035 ... 17274		12695 ... 17696		12360 ... 18125		12031 ... 18561		11708 ... 19006		
18	13030 ... 17281		12689 ... 17703		12354 ... 18132		12025 ... 18569		11702 ... 19013		12
	13024 ... 17288		12683 ... 17710		12349 ... 18139		12020 ... 18576		11697 ... 19021		
19	13018 ... 17295		12678 ... 17717		12343 ... 18146		12014 ... 18583		11692 ... 19028		11
	13012 ... 17302		12672 ... 17724		12338 ... 18154		12009 ... 18591		11686 ... 19036		
20	13007 ... 17309		12666 ... 17731		12332 ... 18161		12004 ... 18598		11681 ... 19043		10
	13001 ... 17316		12661 ... 17738		12327 ... 18168		11998 ... 18605		11676 ... 19051		
21	12995 ... 17323		12655 ... 17745		12321 ... 18175		11993 ... 18613		11670 ... 19058		9
	12990 ... 17330		12650 ... 17752		12316 ... 18182		11987 ... 18620		11665 ... 19066		
22	12984 ... 17337		12644 ... 17760		12310 ... 18190		11982 ... 18627		11660 ... 19073		8
	12978 ... 17344		12638 ... 17767		12305 ... 18197		11976 ... 18635		11654 ... 19081		
23	12972 ... 17351		12633 ... 17774		12299 ... 18204		11971 ... 18642		11649 ... 19088		7
	12967 ... 17358		12627 ... 17781		12293 ... 18211		11966 ... 18650		11644 ... 19096		
24	12961 ... 17365		12622 ... 17788		12288 ... 18219		11960 ... 18657		11638 ... 19103		6
	12955 ... 17372		12616 ... 17795		12282 ... 18226		11955 ... 18664		11633 ... 19111		
25	12950 ... 17379		12610 ... 17802		12277 ... 18233		11949 ... 18672		11628 ... 19118		5
	12944 ... 17386		12605 ... 17809		12271 ... 18240		11944 ... 18679		11622 ... 19126		
26	12938 ... 17393		12599 ... 17816		12266 ... 18248		11939 ... 18686		11617 ... 19133		4
	12932 ... 17400		12593 ... 17824		12260 ... 18255		11933 ... 18694		11612 ... 19141		
27	12927 ... 17407		12588 ... 17831		12255 ... 18262		11928 ... 18701		11606 ... 19148		3
	12921 ... 17414		12582 ... 17838		12249 ... 18269		11922 ... 18709		11601 ... 19156		
28	12915 ... 17421		12577 ... 17845		12244 ... 18277		11917 ... 18716		11596 ... 19163		2
	12910 ... 17428		12571 ... 17852		12238 ... 18284		11912 ... 18723		11590 ... 19171		
29	12904 ... 17435		12566 ... 17859		12233 ... 18291		11906 ... 18731		11585 ... 19178		1
	12898 ... 17442		12560 ... 17866		12227 ... 18298		11901 ... 18738		11580 ... 19186		
30	12893 ... 17449		12554 ... 17873		12222 ... 18306		11895 ... 18746		11575 ... 19193		0
	A B		A B		A B		A B		A B		
	132°00'		131°30'		131°00'		130°30'		130°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	50°00'		50°30'		51°00'		51°30'		52°00'		
	A	B	A	B	A	B	A	B	A	B	
0	11575 ... 19193		11259 ... 19649		10950 ... 20113		10646 ... 20585		10347 ... 21066		30
	11569 ... 19201		11254 ... 19657		10945 ... 20121		10640 ... 20593		10342 ... 21074		
1	11564 ... 19208		11249 ... 19664		10939 ... 20128		10635 ... 20601		10337 ... 21082		29
	11559 ... 19216		11244 ... 19672		10934 ... 20136		10630 ... 20609		10332 ... 21090		
2	11553 ... 19223		11239 ... 19680		10929 ... 20144		10625 ... 20617		10327 ... 21098		28
	11548 ... 19231		11233 ... 19687		10924 ... 20152		10620 ... 20625		10322 ... 21106		
3	11543 ... 19238		11228 ... 19695		10919 ... 20160		10615 ... 20633		10317 ... 21114		27
	11537 ... 19246		11223 ... 19703		10914 ... 20167		10610 ... 20641		10312 ... 21122		
4	11532 ... 19253		11218 ... 19710		10909 ... 20175		10605 ... 20649		10307 ... 21131		26
	11527 ... 19261		11213 ... 19718		10904 ... 20183		10600 ... 20657		10302 ... 21139		
5	11522 ... 19269		11207 ... 19726		10899 ... 20191		10595 ... 20665		10298 ... 21147		25
	11516 ... 19276		11202 ... 19733		10894 ... 20199		10590 ... 20672		10293 ... 21155		
6	11511 ... 19284		11197 ... 19741		10888 ... 20207		10585 ... 20680		10288 ... 21163		24
	11506 ... 19291		11192 ... 19749		10883 ... 20214		10580 ... 20688		10283 ... 21171		
7	11501 ... 19299		11187 ... 19756		10878 ... 20222		10575 ... 20696		10278 ... 21179		23
	11495 ... 19306		11181 ... 19764		10873 ... 20230		10570 ... 20704		10273 ... 21187		
8	11490 ... 19314		11176 ... 19772		10868 ... 20238		10565 ... 20712		10268 ... 21195		22
	11485 ... 19321		11171 ... 19779		10863 ... 20246		10560 ... 20720		10263 ... 21204		
9	11479 ... 19329		11166 ... 19787		10858 ... 20254		10555 ... 20728		10258 ... 21212		21
	11474 ... 19337		11161 ... 19795		10853 ... 20261		10550 ... 20736		10253 ... 21220		
10	11469 ... 19344		11156 ... 19803		10848 ... 20269		10545 ... 20744		10248 ... 21228		20
	11464 ... 19352		11150 ... 19810		10843 ... 20277		10540 ... 20752		10243 ... 21236		
11	11458 ... 19359		11145 ... 19818		10838 ... 20285		10535 ... 20760		10239 ... 21244		19
	11453 ... 19367		11140 ... 19826		10832 ... 20293		10530 ... 20768		10234 ... 21252		
12	11448 ... 19375		11135 ... 19834		10827 ... 20301		10525 ... 20776		10229 ... 21260		18
	11443 ... 19382		11130 ... 19841		10822 ... 20308		10520 ... 20784		10224 ... 21269		
13	11437 ... 19390		11124 ... 19849		10817 ... 20316		10515 ... 20792		10219 ... 21277		17
	11432 ... 19397		11119 ... 19857		10812 ... 20324		10510 ... 20800		10214 ... 21285		
14	11427 ... 19405		11114 ... 19864		10807 ... 20332		10505 ... 20808		10209 ... 21293		16
	11421 ... 19412		11109 ... 19872		10802 ... 20340		10500 ... 20816		10204 ... 21301		
15	11416 ... 19420		11104 ... 19880		10797 ... 20348		10496 ... 20824		10199 ... 21309		15
	11411 ... 19428		11099 ... 19888		10792 ... 20356		10491 ... 20832		10195 ... 21318		
16	11406 ... 19435		11094 ... 19895		10787 ... 20364		10486 ... 20840		10190 ... 21326		14
	11400 ... 19443		11088 ... 19903		10782 ... 20371		10481 ... 20848		10185 ... 21334		
17	11395 ... 19450		11083 ... 19911		10777 ... 20379		10476 ... 20856		10180 ... 21342		13
	11390 ... 19458		11078 ... 19918		10772 ... 20387		10471 ... 20864		10175 ... 21350		
18	11385 ... 19466		11073 ... 19926		10767 ... 20395		10466 ... 20872		10170 ... 21358		12
	11380 ... 19473		11068 ... 19934		10761 ... 20403		10461 ... 20880		10165 ... 21367		
19	11374 ... 19481		11063 ... 19942		10756 ... 20411		10456 ... 20888		10160 ... 21375		11
	11369 ... 19488		11057 ... 19949		10751 ... 20419		10451 ... 20897		10155 ... 21383		
20	11364 ... 19496		11052 ... 19957		10746 ... 20427		10446 ... 20905		10151 ... 21391		10
	11359 ... 19504		11047 ... 19965		10741 ... 20435		10441 ... 20913		10146 ... 21399		
21	11353 ... 19511		11042 ... 19973		10736 ... 20442		10436 ... 20921		10141 ... 21407		9
	11348 ... 19519		11037 ... 19980		10731 ... 20450		10431 ... 20929		10136 ... 21416		
22	11343 ... 19527		11032 ... 19988		10726 ... 20458		10426 ... 20937		10131 ... 21424		8
	11338 ... 19534		11027 ... 19996		10721 ... 20466		10421 ... 20945		10126 ... 21432		
23	11332 ... 19542		11021 ... 20004		10716 ... 20474		10416 ... 20953		10121 ... 21440		7
	11327 ... 19549		11016 ... 20012		10711 ... 20482		10411 ... 20961		10116 ... 21448		
24	11322 ... 19557		11011 ... 20019		10706 ... 20490		10406 ... 20969		10112 ... 21457		6
	11317 ... 19565		11006 ... 20027		10701 ... 20498		10401 ... 20977		10107 ... 21465		
25	11311 ... 19572		11001 ... 20035		10696 ... 20506		10396 ... 20985		10102 ... 21473		5
	11306 ... 19580		10996 ... 20043		10691 ... 20514		10391 ... 20993		10097 ... 21481		
26	11301 ... 19588		10991 ... 20050		10686 ... 20522		10386 ... 21001		10092 ... 21489		4
	11296 ... 19595		10986 ... 20058		10681 ... 20529		10381 ... 21009		10087 ... 21498		
27	11291 ... 19603		10980 ... 20066		10676 ... 20537		10376 ... 21017		10082 ... 21506		3
	11285 ... 19611		10975 ... 20074		10671 ... 20545		10372 ... 21025		10078 ... 21514		
28	11280 ... 19618		10970 ... 20082		10666 ... 20553		10367 ... 21033		10073 ... 21522		2
	11275 ... 19626		10965 ... 20089		10661 ... 20561		10362 ... 21042		10068 ... 21531		
29	11270 ... 19634		10960 ... 20097		10656 ... 20569		10357 ... 21050		10063 ... 21539		1
	11265 ... 19641		10955 ... 20105		10651 ... 20577		10352 ... 21058		10058 ... 21547		
30	11259 ... 19649		10950 ... 20113		10646 ... 20585		10347 ... 21066		10053 ... 21555		0
	A	B	A	B	A	B	A	B	A	B	
	129°30'		129°00'		128°30'		128°00'		127°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	52°30'		53°00'		53°30'		54°00'		54°30'		
	A	B	A	B	A	B	A	B	A	B	
0	10053 ...	21555	9765 ...	22054	9482 ...	22561	9204 ...	23078	8931 ...	23605	30
	10049 ...	21563	9760 ...	22062	9477 ...	22570	9200 ...	23087	8927 ...	23613	
1	10044 ...	21572	9756 ...	22070	9473 ...	22578	9195 ...	23095	8922 ...	23622	29
	10039 ...	21580	9751 ...	22079	9468 ...	22587	9190 ...	23104	8918 ...	23631	
2	10034 ...	21588	9746 ...	22087	9463 ...	22595	9186 ...	23113	8913 ...	23640	28
	10029 ...	21596	9741 ...	22096	9459 ...	22604	9181 ...	23122	8909 ...	23649	
3	10024 ...	21605	9737 ...	22104	9454 ...	22612	9177 ...	23130	8904 ...	23658	27
	10019 ...	21613	9732 ...	22112	9449 ...	22621	9172 ...	23139	8900 ...	23667	
4	10015 ...	21621	9727 ...	22121	9445 ...	22630	9168 ...	23148	8895 ...	23675	26
	10010 ...	21629	9722 ...	22129	9440 ...	22638	9163 ...	23156	8891 ...	23684	
5	10005 ...	21638	9718 ...	22138	9435 ...	22647	9158 ...	23165	8886 ...	23693	25
	10000 ...	21646	9713 ...	22146	9431 ...	22655	9154 ...	23174	8882 ...	23702	
6	9995 ...	21654	9708 ...	22154	9426 ...	22664	9149 ...	23183	8877 ...	23711	24
	9990 ...	21662	9703 ...	22163	9421 ...	22672	9145 ...	23191	8873 ...	23720	
7	9986 ...	21671	9699 ...	22171	9417 ...	22681	9140 ...	23200	8868 ...	23729	23
	9981 ...	21679	9694 ...	22180	9412 ...	22690	9136 ...	23209	8864 ...	23738	
8	9976 ...	21687	9689 ...	22188	9407 ...	22698	9131 ...	23218	8859 ...	23747	22
	9971 ...	21696	9684 ...	22197	9403 ...	22707	9126 ...	23226	8855 ...	23755	
9	9966 ...	21704	9680 ...	22205	9398 ...	22715	9122 ...	23235	8850 ...	23764	21
	9962 ...	21712	9675 ...	22213	9394 ...	22724	9117 ...	23244	8846 ...	23773	
10	9957 ...	21720	9670 ...	22222	9389 ...	22732	9113 ...	23252	8842 ...	23782	20
	9952 ...	21729	9665 ...	22230	9384 ...	22741	9108 ...	23261	8837 ...	23791	
11	9947 ...	21737	9661 ...	22239	9380 ...	22750	9104 ...	23270	8833 ...	23800	19
	9942 ...	21745	9656 ...	22247	9375 ...	22758	9099 ...	23279	8828 ...	23809	
12	9937 ...	21754	9651 ...	22256	9370 ...	22767	9094 ...	23288	8824 ...	23818	18
	9933 ...	21762	9647 ...	22264	9366 ...	22775	9090 ...	23296	8819 ...	23827	
13	9928 ...	21770	9642 ...	22272	9361 ...	22784	9085 ...	23305	8815 ...	23836	17
	9923 ...	21778	9637 ...	22281	9356 ...	22793	9081 ...	23314	8810 ...	23845	
14	9918 ...	21787	9632 ...	22289	9352 ...	22801	9076 ...	23323	8806 ...	23854	16
	9913 ...	21795	9628 ...	22298	9347 ...	22810	9072 ...	23331	8801 ...	23863	
15	9909 ...	21803	9623 ...	22306	9342 ...	22818	9067 ...	23340	8797 ...	23871	15
	9904 ...	21812	9618 ...	22315	9338 ...	22827	9063 ...	23349	8792 ...	23880	
16	9899 ...	21820	9614 ...	22323	9333 ...	22836	9058 ...	23358	8788 ...	23889	14
	9894 ...	21828	9609 ...	22332	9329 ...	22844	9054 ...	23366	8783 ...	23898	
17	9889 ...	21837	9604 ...	22340	9324 ...	22853	9049 ...	23375	8779 ...	23907	13
	9885 ...	21845	9599 ...	22349	9319 ...	22862	9044 ...	23384	8775 ...	23916	
18	9880 ...	21853	9595 ...	22357	9315 ...	22870	9040 ...	23393	8770 ...	23925	12
	9875 ...	21862	9590 ...	22366	9310 ...	22879	9035 ...	23402	8766 ...	23934	
19	9870 ...	21870	9585 ...	22374	9305 ...	22887	9031 ...	23410	8761 ...	23943	11
	9865 ...	21878	9581 ...	22382	9301 ...	22896	9026 ...	23419	8757 ...	23952	
20	9861 ...	21887	9576 ...	22391	9296 ...	22905	9022 ...	23428	8752 ...	23961	10
	9856 ...	21895	9571 ...	22399	9292 ...	22913	9017 ...	23437	8748 ...	23970	
21	9851 ...	21903	9566 ...	22408	9287 ...	22922	9013 ...	23446	8743 ...	23979	9
	9846 ...	21912	9562 ...	22416	9282 ...	22931	9008 ...	23454	8739 ...	23988	
22	9841 ...	21920	9557 ...	22425	9278 ...	22939	9004 ...	23463	8734 ...	23997	8
	9837 ...	21928	9552 ...	22433	9273 ...	22948	8999 ...	23472	8730 ...	24006	
23	9832 ...	21937	9548 ...	22442	9269 ...	22957	8995 ...	23481	8726 ...	24015	7
	9827 ...	21945	9543 ...	22450	9264 ...	22965	8990 ...	23490	8721 ...	24024	
24	9822 ...	21953	9538 ...	22459	9259 ...	22974	8985 ...	23498	8717 ...	24033	6
	9818 ...	21962	9534 ...	22467	9255 ...	22983	8981 ...	23507	8712 ...	24042	
25	9813 ...	21970	9529 ...	22476	9250 ...	22991	8976 ...	23516	8708 ...	24051	5
	9808 ...	21978	9524 ...	22484	9246 ...	23000	8972 ...	23525	8703 ...	24060	
26	9803 ...	21987	9520 ...	22493	9241 ...	23009	8967 ...	23534	8699 ...	24069	4
	9798 ...	21995	9515 ...	22501	9236 ...	23017	8963 ...	23543	8694 ...	24078	
27	9794 ...	22003	9510 ...	22510	9232 ...	23026	8958 ...	23551	8690 ...	24037	3
	9789 ...	22012	9505 ...	22519	9227 ...	23035	8954 ...	23560	8686 ...	24096	
28	9784 ...	22020	9501 ...	22527	9223 ...	23043	8949 ...	23569	8681 ...	24105	2
	9779 ...	22029	9496 ...	22536	9218 ...	23052	8945 ...	23578	8677 ...	24114	
29	9775 ...	22037	9491 ...	22544	9213 ...	23061	8940 ...	23587	8672 ...	24123	1
	9770 ...	22045	9487 ...	22553	9209 ...	23069	8936 ...	23596	8668 ...	24132	
30	9765 ...	22054	9482 ...	22561	9204 ...	23078	8931 ...	23605	8663 ...	24141	0
	A	B	A	B	A	B	A	B	A	B	
	127°00'		126°30'		126°00'		125°30'		125°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	55°00'		55°30'		56°00'		56°30'		57°00'		
	A	B	A	B	A	B	A	B	A	B	
0	8663	24141	8401	24687	8143	25244	7889	25811	7641	26389	30
	8659	24150	8396	24696	8138	25253	7885	25821	7637	26399	
1	8655	24159	8392	24706	8134	25263	7881	25830	7633	26409	29
	8650	24168	8388	24715	8130	25272	7877	25840	7629	26418	
2	8646	24177	8383	24724	8125	25281	7873	25849	7624	26428	27
	8641	24186	8379	24733	8121	25291	7868	25859	7620	26438	
3	8637	24195	8375	24742	8117	25300	7864	25868	7616	26447	27
	8633	24204	8370	24752	8113	25309	7860	25878	7612	26457	
4	8628	24213	8366	24761	8108	25319	7856	25887	7608	26467	26
	8624	24222	8362	24770	8104	25328	7852	25897	7604	26477	
5	8619	24231	8357	24779	8100	25338	7848	25907	7600	26486	25
	8615	24240	8353	24788	8096	25347	7843	25916	7596	26496	
6	8611	24249	8349	24798	8092	25356	7839	25926	7592	26506	24
	8606	24258	8344	24807	8087	25366	7835	25935	7588	26516	
7	8602	24267	8340	24816	8083	25375	7831	25945	7584	26526	23
	8597	24276	8336	24825	8079	25385	7827	25954	7579	26535	
8	8593	24286	8331	24835	8075	25394	7823	25964	7575	26545	22
	8589	24295	8327	24844	8070	25403	7818	25974	7571	26555	
9	8584	24304	8323	24853	8066	25413	7814	25983	7567	26565	21
	8580	24313	8318	24862	8062	25422	7810	25993	7563	26574	
10	8575	24322	8314	24872	8058	25432	7806	26002	7559	26584	20
	8571	24331	8310	24881	8053	25441	7802	26012	7555	26594	
11	8567	24340	8305	24890	8049	25451	7798	26022	7551	26604	19
	8562	24349	8301	24899	8045	25460	7793	26031	7547	26614	
12	8558	24358	8297	24909	8041	25469	7789	26041	7543	26623	18
	8553	24367	8292	24918	8036	25479	7785	26051	7539	26633	
13	8549	24376	8288	24927	8032	25488	7781	26060	7535	26643	17
	8545	24385	8284	24936	8028	25498	7777	26070	7531	26653	
14	8540	24395	8280	24946	8024	25507	7773	26079	7526	26663	16
	8536	24404	8275	24955	8020	25517	7769	26089	7522	26672	
15	8531	24413	8271	24964	8015	25526	7764	26099	7518	26682	15
	8527	24422	8267	24973	8011	25536	7760	26108	7514	26692	
16	8523	24431	8262	24983	8007	25545	7756	26118	7510	26702	14
	8518	24440	8258	24992	8003	25554	7752	26128	7506	26712	
17	8514	24449	8254	25001	7998	25564	7748	26137	7502	26722	13
	8510	24458	8249	25011	7994	25573	7744	26147	7498	26731	
18	8505	24467	8245	25020	7990	25583	7740	26157	7494	26741	12
	8501	24477	8241	25029	7986	25592	7736	26166	7490	26751	
19	8496	24486	8237	25038	7982	25602	7731	26176	7486	26761	11
	8492	24495	8232	25048	7977	25611	7727	26185	7482	26771	
20	8488	24504	8228	25057	7973	25621	7723	26195	7478	26781	10
	8483	24513	8224	25066	7969	25630	7719	26205	7474	26790	
21	8479	24522	8219	25076	7965	25640	7715	26214	7470	26800	9
	8475	24531	8215	25085	7961	25649	7711	26224	7466	26810	
22	8470	24540	8211	25094	7956	25659	7707	26234	7462	26820	8
	8466	24550	8207	25104	7952	25668	7702	26244	7458	26830	
23	8461	24559	8202	25113	7948	25678	7698	26253	7453	26840	7
	8457	24568	8198	25122	7944	25687	7694	26263	7449	26850	
24	8453	24577	8194	25132	7940	25697	7690	26273	7445	26860	6
	8448	24586	8189	25141	7935	25706	7686	26282	7441	26869	
25	8444	24595	8185	25150	7931	25716	7682	26292	7437	26879	5
	8440	24605	8181	25160	7927	25725	7678	26302	7433	26889	
26	8435	24614	8177	25169	7923	25735	7674	26311	7429	26899	4
	8431	24623	8172	25178	7919	25744	7670	26321	7425	26909	
27	8427	24632	8168	25188	7914	25754	7665	26331	7421	26919	3
	8422	24641	8164	25197	7910	25763	7661	26340	7417	26929	
28	8418	24650	8160	25206	7906	25773	7657	26350	7413	26939	2
	8414	24660	8155	25216	7902	25782	7653	26360	7409	26949	
29	8409	24669	8151	25225	7898	25792	7649	26370	7405	26958	1
	8405	24678	8147	25234	7893	25801	7645	26379	7401	26968	
30	8401	24687	8143	25244	7889	25811	7641	26389	7397	26978	0
	A	B	A	B	A	B	A	B	A	B	
	124°30'		124°00'		123°30'		123°00'		122°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	57°30'		58°00'		58°30'		59°00'		59°30'		
	A	B	A	B	A	B	A	B	A	B	
0	7397	26978	7158	27579	6923	28191	6693	28816	6468	29453	30
1	7393	26988	7154	27589	6920	28202	6690	28827	6464	29464	29
	7389	26998	7150	27599	6916	28212	6686	28837	6460	29475	
2	7385	27008	7146	27609	6912	28222	6682	28848	6457	29485	28
	7381	27018	7142	27619	6908	28233	6678	28858	6453	29496	
3	7377	27028	7138	27630	6904	28243	6674	28869	6449	29507	27
	7373	27038	7134	27640	6900	28253	6671	28879	6446	29517	
4	7369	27048	7130	27650	6896	28264	6667	28890	6442	29528	26
	7365	27058	7126	27660	6892	28274	6663	28900	6438	29539	
5	7361	27068	7122	27670	6889	28284	6659	28911	6434	29550	25
	7357	27078	7118	27680	6885	28295	6655	28921	6431	29560	
6	7353	27088	7115	27690	6881	28305	6652	28932	6427	29571	24
	7349	27098	7111	27701	6877	28315	6648	28942	6423	29582	
7	7345	27107	7107	27711	6873	28326	6644	28953	6420	29593	23
	7341	27117	7103	27721	6869	28336	6640	28964	6416	29604	
8	7337	27127	7099	27731	6865	28346	6637	28974	6412	29614	22
	7333	27137	7095	27741	6862	28357	6633	28985	6409	29625	
9	7329	27147	7091	27751	6858	28367	6629	28995	6405	29636	21
	7325	27157	7087	27761	6854	28378	6625	29006	6401	29647	
10	7321	27167	7083	27772	6850	28388	6622	29016	6397	29657	20
	7317	27177	7079	27782	6846	28398	6618	29027	6394	29668	
11	7313	27187	7075	27792	6842	28409	6614	29038	6390	29679	19
	7309	27197	7071	27802	6839	28419	6610	29048	6386	29690	
12	7305	27207	7068	27812	6835	28429	6607	29059	6383	29701	18
	7301	27217	7064	27823	6831	28440	6603	29069	6379	29711	
13	7297	27227	7060	27833	6827	28450	6599	29080	6375	29722	17
	7293	27237	7056	27843	6823	28461	6595	29091	6372	29733	
14	7289	27247	7052	27853	6819	28471	6591	29101	6368	29744	16
	7285	27257	7048	27863	6815	28481	6588	29112	6364	29755	
15	7281	27267	7044	27874	6812	28492	6584	29122	6361	29766	15
	7277	27277	7040	27884	6808	28502	6580	29133	6357	29776	
16	7273	27287	7036	27894	6804	28513	6576	29144	6353	29787	14
	7269	27297	7032	27904	6800	28523	6573	29154	6349	29798	
17	7265	27307	7028	27914	6796	28533	6569	29165	6346	29809	13
	7261	27317	7024	27925	6792	28544	6565	29175	6342	29820	
18	7257	27327	7021	27935	6789	28554	6561	29186	6338	29831	12
	7253	27337	7017	27945	6785	28565	6558	29197	6335	29841	
19	7249	27347	7013	27955	6781	28575	6554	29207	6331	29852	11
	7245	27357	7009	27965	6777	28586	6550	29218	6327	29863	
20	7241	27367	7005	27976	6773	28596	6546	29229	6324	29874	10
	7237	27377	7001	27986	6770	28607	6543	29239	6320	29885	
21	7233	27387	6997	27996	6766	28617	6539	29250	6316	29896	9
	7229	27398	6993	28006	6762	28627	6535	29261	6313	29907	
22	7225	27408	6989	28017	6758	28638	6531	29271	6309	29917	8
	7221	27418	6985	28027	6754	28648	6528	29282	6305	29929	
23	7217	27428	6982	28037	6750	28659	6524	29293	6302	29939	7
	7213	27438	6978	28047	6747	28669	6520	29303	6298	29950	
24	7209	27448	6974	28058	6743	28680	6516	29314	6294	29961	6
	7205	27458	6970	28068	6739	28690	6513	29325	6291	29972	
25	7201	27468	6966	28078	6735	28701	6509	29335	6287	29983	5
	7197	27478	6962	28089	6731	28711	6505	29346	6283	29994	
26	7193	27488	6958	28099	6728	28722	6502	29357	6280	30005	4
	7190	27498	6954	28109	6724	28732	6498	29367	6276	30015	
27	7186	27508	6951	28119	6720	28743	6494	29378	6272	30026	3
	7182	27518	6947	28130	6716	28753	6490	29389	6269	30037	
28	7178	27528	6943	28140	6712	28763	6487	29399	6265	30048	2
	7174	27539	6939	28150	6709	28774	6483	29410	6261	30059	
29	7170	27549	6935	28161	6705	28784	6479	29421	6258	30070	1
	7166	27559	6931	28171	6701	28795	6475	29432	6254	30081	
30	7162	27569	6927	28181	6697	28806	6472	29442	6251	30092	0
	7158	27579	6923	28191	6693	28816	6468	29453	6247	30103	
	A	B	A	B	A	B	A	B	A	B	
	122°00'		121°30'		121°00'		120°30'		120°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	60°00'		60°30'		61°00'		61°30'		62°00'		
	A	B	A	B	A	B	A	B	A	B	
0	6247	30103	6030	30766	5818	31443	5610	32134	5408	32839	30
1	6243	30114	6027	30777	5815	31454	5607	32145	5403	32851	29
	6240	30125	6023	30788	5811	31466	5603	32157	5400	32863	
2	6236	30136	6020	30800	5808	31477	5600	32169	5396	32875	28
	6232	30147	6016	30811	5804	31488	5596	32180	5393	32887	
3	6229	30158	6012	30822	5801	31500	5593	32192	5390	32898	27
	6225	30169	6009	30833	5797	31511	5590	32204	5386	32910	
4	6221	30180	6005	30844	5794	31523	5586	32215	5383	32922	26
	6218	30191	6002	30856	5790	31534	5583	32227	5380	32934	
5	6214	30202	5998	30867	5787	31546	5579	32239	5376	32946	25
	6210	30213	5995	30878	5783	31557	5575	32250	5373	32958	
6	6207	30224	5991	30889	5780	31569	5572	32262	5370	32970	24
	6203	30235	5987	30900	5776	31580	5569	32274	5366	32982	
7	6200	30246	5984	30912	5773	31591	5566	32285	5363	32994	23
	6196	30256	5980	30923	5769	31603	5562	32297	5360	33006	
8	6192	30267	5977	30934	5766	31614	5559	32309	5356	33018	22
	6189	30278	5973	30945	5762	31626	5555	32320	5353	33030	
9	6185	30289	5970	30956	5759	31637	5552	32332	5350	33042	21
	6181	30300	5966	30968	5755	31649	5549	32344	5346	33054	
10	6178	30311	5963	30979	5752	31660	5545	32355	5343	33066	20
	6174	30322	5959	30990	5748	31672	5542	32367	5340	33077	
11	6171	30334	5955	31001	5745	31683	5538	32379	5336	33089	19
	6167	30345	5952	31013	5741	31694	5535	32391	5333	33101	
12	6163	30355	5948	31024	5738	31706	5532	32402	5330	33113	18
	6160	30367	5945	31035	5734	31717	5528	32414	5326	33125	
13	6156	30378	5941	31046	5731	31729	5525	32426	5323	33137	17
	6152	30389	5938	31058	5727	31740	5521	32438	5320	33149	
14	6149	30400	5934	31069	5724	31752	5518	32449	5316	33161	16
	6145	30411	5931	31080	5720	31763	5515	32461	5313	33173	
15	6142	30422	5927	31091	5717	31775	5511	32473	5310	33185	15
	6138	30433	5924	31103	5714	31786	5508	32484	5306	33197	
16	6134	30444	5920	31114	5710	31798	5504	32496	5303	33209	14
	6131	30455	5917	31125	5707	31809	5501	32508	5300	33221	
17	6127	30466	5913	31137	5703	31821	5498	32520	5296	33233	13
	6124	30477	5909	31148	5700	31833	5494	32532	5293	33245	
18	6120	30488	5906	31159	5696	31844	5491	32543	5290	33257	12
	6116	30499	5902	31170	5693	31856	5487	32555	5286	33269	
19	6113	30510	5899	31182	5689	31867	5484	32567	5283	33281	11
	6109	30521	5895	31193	5686	31879	5481	32579	5280	33293	
20	6106	30532	5892	31204	5682	31890	5477	32590	5276	33306	10
	6102	30544	5888	31216	5679	31902	5474	32602	5273	33318	
21	6098	30555	5885	31227	5675	31913	5470	32614	5270	33330	9
	6095	30566	5881	31238	5672	31925	5467	32625	5266	33342	
22	6091	30577	5878	31250	5669	31936	5464	32638	5263	33354	8
	6088	30588	5874	31261	5665	31948	5460	32649	5260	33366	
23	6084	30599	5871	31272	5662	31960	5457	32661	5257	33378	7
	6080	30610	5867	31284	5658	31971	5454	32673	5253	33390	
24	6077	30621	5864	31295	5655	31983	5450	32685	5250	33402	6
	6073	30632	5860	31306	5651	31994	5447	32697	5247	33414	
25	6070	30643	5857	31318	5648	32006	5443	32709	5243	33426	5
	6066	30655	5853	31329	5644	32018	5440	32720	5240	33438	
26	6062	30666	5850	31340	5641	32029	5437	32732	5237	33450	4
	6059	30677	5846	31352	5638	32041	5433	32744	5233	33462	
27	6055	30688	5843	31363	5634	32052	5430	32756	5230	33475	3
	6052	30699	5839	31375	5631	32064	5427	32768	5227	33487	
28	6048	30710	5836	31386	5627	32076	5423	32780	5224	33499	2
	6045	30721	5832	31397	5624	32087	5420	32792	5220	33511	
29	6041	30733	5829	31409	5620	32099	5417	32803	5217	33523	1
	6037	30744	5825	31420	5617	32110	5413	32815	5214	33535	
30	6034	30755	5822	31431	5614	32122	5410	32827	5210	33547	0
	6030	30766	5818	31443	5610	32134	5406	32839	5207	33559	
	A	B	A	B	A	B	A	B	A	B	
	119°30'		119°00'		118°30'		118°00'		117°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	62°30'		63°00'		63°30'		64°00'		64°30'		
	A	B	A	B	A	B	A	B	A	B	
0	5207	33559	5012	34295	4821	35047	4634	35816	4451	36602	30
1	5204	33572	5009	34308	4818	35060	4631	35829	4448	36615	29
	5200	33584	5005	34320	4815	35073	4628	35842	4445	36628	
	5197	33596	5002	34332	4811	35085	4625	35855	4442	36641	
2	5194	33608	4999	34345	4808	35098	4622	35868	4439	36655	28
	5191	33620	4996	34357	4805	35111	4619	35881	4436	36668	
3	5187	33632	4993	34370	4802	35123	4615	35894	4433	36681	27
	5184	33644	4989	34382	4799	35136	4612	35907	4430	36694	
4	5181	33657	4986	34395	4796	35149	4609	35920	4427	36708	26
	5178	33669	4983	34407	4793	35161	4606	35933	4424	36721	
5	5174	33681	4980	34420	4789	35174	4603	35946	4421	36734	25
	5171	33693	4977	34432	4786	35187	4600	35959	4418	36747	
6	5168	33705	4973	34444	4783	35200	4597	35972	4415	36761	24
	5164	33717	4970	34457	4780	35212	4594	35985	4412	36774	
7	5161	33730	4967	34469	4777	35225	4591	35998	4409	36787	23
	5158	33742	4964	34482	4774	35238	4588	36011	4406	36801	
8	5155	33754	4961	34494	4771	35251	4585	36024	4403	36814	22
	5155	33766	4957	34507	4767	35263	4582	36037	4400	36827	
9	5148	33779	4954	34519	4764	35276	4579	36050	4397	36841	21
	5145	33791	4951	34532	4761	35289	4576	36063	4394	36854	
10	5142	33803	4948	34544	4758	35302	4573	36076	4391	36867	20
	5138	33815	4945	34557	4755	35314	4569	36089	4388	36881	
11	5135	33827	4941	34569	4752	35327	4566	36102	4385	36894	19
	5132	33840	4938	34582	4749	35340	4563	36115	4382	36907	
12	5128	33852	4935	34594	4746	35353	4560	36128	4379	36921	18
	5125	33864	4932	34607	4742	35365	4557	36141	4376	36934	
13	5122	33876	4929	34619	4739	35378	4554	36154	4373	36948	17
	5119	33889	4925	34632	4736	35391	4551	36167	4370	36961	
14	5115	33901	4922	34644	4733	35404	4548	36180	4367	36974	16
	5112	33913	4919	34657	4730	35417	4545	36193	4364	36988	
15	5109	33925	4916	34669	4727	35429	4542	36206	4361	37001	15
	5106	33938	4913	34682	4724	35442	4529	36220	4358	37014	
16	5102	33950	4910	34694	4721	35455	4536	36233	4355	37028	14
	5099	33962	4906	34707	4718	35468	4533	36246	4352	37041	
17	5096	33974	4903	34719	4714	35481	4530	36259	4349	37055	13
	5093	33987	4900	34732	4711	35493	4527	36272	4346	37068	
18	5089	33999	4897	34744	4708	35506	4524	36285	4343	37081	12
	5086	34011	4894	34757	4705	35519	4521	36298	4340	37095	
19	5083	34024	4890	34770	4702	35532	4518	36311	4337	37108	11
	5080	34036	4887	34782	4699	35545	4515	36325	4334	37122	
20	5076	34048	4884	34795	4696	35558	4512	36338	4332	37135	10
	5073	34061	4881	34807	4693	35571	4509	36351	4329	37149	
21	5070	34073	4878	34820	4690	35583	4506	36364	4326	37162	9
	5067	34085	4875	34832	4686	35596	4503	36377	4323	37176	
22	5064	34097	4871	34845	4683	35609	4500	36390	4320	37189	8
	5060	34110	4868	34858	4680	35622	4497	36403	4317	37203	
23	5057	34122	4865	34870	4677	35635	4493	36417	4314	37216	7
	5054	34134	4862	34883	4674	35648	4490	36430	4311	37229	
24	5051	34147	4859	34896	4671	35661	4487	36443	4308	37243	6
	5047	34159	4856	34908	4668	35674	4484	36456	4305	37256	
25	5044	34172	4852	34921	4665	35686	4481	36469	4302	37270	5
	5041	34184	4849	34933	4662	35699	4478	36483	4299	37283	
26	5038	34196	4846	34946	4659	35712	4475	36496	4296	37297	4
	5034	34209	4843	34959	4656	35725	4472	36509	4293	37310	
27	5031	34221	4840	34971	4652	35738	4469	36522	4290	37324	3
	5028	34233	4837	34984	4649	35751	4466	36535	4287	37337	
28	5025	34246	4833	34997	4646	35764	4463	36549	4284	37351	2
	5022	34258	4830	35009	4643	35777	4460	36562	4281	37365	
29	5018	34270	4827	35022	4640	35790	4457	36575	4278	37378	1
	5015	34283	4824	35035	4637	35803	4454	36588	4275	37392	
30	5012	34295	4821	35047	4634	35816	4451	36602	4272	37405	0
	A	B	A	B	A	B	A	B	A	B	
	117°00'		116°30'		116°00'		115°30'		115°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	65°00'		65°30'		66°00'		66°30'		67°00'		
	A	B	A	B	A	B	A	B	A	B	
0	4272	37405	4098	38227	3927	39069	3760	39930	3597	40812	30
	4269	37419	4095	38241	3924	39083	3757	39945	3595	40827	
1	4266	37432	4092	38255	3921	39097	3755	39959	3592	40842	29
	4264	37446	4089	38269	3918	39111	3752	39974	3589	40857	
2	4261	37459	4086	38283	3916	39125	3749	39988	3587	40872	28
	4258	37473	4083	38297	3913	39140	3746	40003	3584	40887	
3	4255	37487	4080	38311	3910	39154	3744	40017	3581	40902	27
	4252	37500	4078	38324	3907	39168	3741	40032	3579	40916	
4	4249	37514	4075	38338	3904	39182	3738	40046	3576	40931	26
	4246	37527	4072	38352	3902	39197	3735	40061	3573	40946	
5	4243	37541	4069	38366	3899	39211	3733	40076	3571	40961	25
	4240	37554	4066	38380	3896	39225	3730	40090	3568	40976	
6	4237	37568	4063	38394	3893	39239	3727	40105	3565	40991	24
	4234	37582	4060	38408	3890	39254	3725	40119	3563	41006	
7	4231	37595	4057	38422	3888	39268	3722	40134	3560	41021	23
	4228	37609	3055	38436	3885	39282	3719	40149	3557	41036	
8	4225	37623	4052	38450	3882	39296	3716	40163	3555	41051	22
	4222	37636	4049	38464	3879	39311	3714	40178	3552	41066	
9	4220	37650	4046	38478	3876	39325	3711	40192	3549	41081	21
	4217	37663	4043	38492	3874	39339	3708	40207	3547	41096	
10	4214	37677	4040	38506	3871	39353	3705	40222	3544	41111	20
	4211	37691	4037	38520	3868	39368	3703	40236	3541	41126	
11	4208	37704	4035	38533	3865	39382	3700	40251	3539	41141	19
	4205	37718	4032	38547	3863	39396	3697	40266	3536	41156	
12	4202	37732	4029	38561	3860	39411	3695	40280	3533	41171	18
	4199	37745	4026	38575	3857	39425	3692	40295	3531	41186	
13	4196	37759	4023	38589	3854	39439	3689	40310	3528	41201	17
	4193	37773	4020	38603	3851	39454	3686	40324	3525	41216	
14	4190	37786	4017	38617	3849	39468	3684	40339	3523	41231	16
	4187	37800	4015	38631	3846	39482	3681	40354	3520	41246	
15	4185	37814	4012	38645	3843	39497	3678	40368	3517	41261	15
	4182	37828	4009	38660	3840	39511	3676	40383	3515	41276	
16	4179	37841	4006	38674	3838	39525	3673	40398	3512	41291	14
	4176	37855	4003	38688	3835	39540	3670	40413	3509	41307	
17	4173	37869	4000	38702	3832	39554	3667	40427	3507	41322	13
	4170	37882	3998	38716	3829	39569	3665	40442	3504	41337	
18	4167	37896	3995	38730	3826	39583	3662	40457	3502	41352	12
	4164	37910	3992	38744	3824	39597	3659	40471	3499	41367	
19	4161	37924	3989	38758	3821	39612	3657	40486	3496	41382	11
	4158	37937	3986	38772	3818	39626	3654	40501	3494	41397	
20	4155	37951	3983	38786	3815	39641	3651	40516	3491	41412	10
	4153	37965	3981	38800	3813	39655	3648	40530	3488	41427	
21	4150	37979	3978	38814	3810	39669	3646	40545	3486	41443	9
	4147	37992	3975	38828	3807	39684	3643	40560	3483	41458	
22	4144	38006	3972	38842	3804	39698	3640	40575	3480	41473	8
	4141	38020	3969	38856	3801	39713	3638	40590	3478	41488	
23	4138	38034	3966	38871	3799	39727	3635	40604	3475	41503	7
	4135	38048	3964	38885	3796	39742	3632	40619	3473	41518	
24	4132	38061	3961	38899	3793	39756	3630	40634	3470	41533	6
	4129	38075	3958	38913	3790	39771	3627	40649	3467	41549	
25	4127	38089	3955	38927	3788	39785	3624	40664	3465	41564	5
	4124	38103	3952	38941	3785	39799	3622	40678	3462	41579	
26	4121	38117	3949	38955	3782	39814	3619	40693	3459	41594	4
	4118	38130	3947	38969	3779	39828	3616	40708	3457	41609	
27	4115	38144	3944	38984	3777	39843	3613	40723	3454	41625	3
	4112	38158	3941	38998	3774	39857	3611	40738	3452	41640	
28	4109	38172	3938	39012	3771	39872	3608	40753	3449	41655	2
	4106	38186	3935	39026	3768	39886	3605	40768	3446	41670	
29	4103	38200	3933	39040	3766	39901	3603	40782	3444	41685	1
	4101	38213	3930	39054	3763	39915	3600	40797	3441	41701	
30	4098	38227	3927	39069	3760	39930	3597	40812	3438	41716	0
	A	B	A	B	A	B	A	B	A	B	
	114°30'		114°00'		113°30'		113°00'		112°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	67°30'		68°00'		68°30'		69°00'		69°30'		
	A	B	A	B	A	B	A	B	A	B	
0	3438	41716	3283	42642	3132	43592	2985	44567	2841	45567	30
	3436	41731	3281	42658	3130	43608	2982	44583	2839	45584	
1	3433	41746	3278	42674	3127	43624	2980	44600	2836	45601	29
	3431	41762	3276	42689	3125	43641	2978	44616	2834	45618	
2	3428	41777	3273	42705	3122	43657	2975	44633	2832	45635	28
	3425	41792	3271	42721	3120	43673	2973	44649	2829	45652	
3	3423	41808	3268	42738	3117	43689	2970	44666	2827	45669	27
	3420	41823	3266	42752	3115	43705	2968	44682	2825	45686	
4	3418	41838	3263	42768	3112	43721	2965	44699	2822	45703	26
	3415	41853	3260	42783	3110	43737	2963	44715	2820	45720	
5	3412	41869	3258	42799	3107	43753	2961	44732	2818	45737	25
	3410	41884	3255	42815	3105	43769	2958	44748	2815	45754	
6	3407	41899	3253	42830	3102	43785	2956	44765	2813	45771	24
	3404	41915	3250	42846	3100	43801	2953	44782	2811	45788	
7	3402	41930	3248	42862	3097	43818	2951	44798	2808	45805	23
	3399	41945	3245	42878	3095	43834	2949	44815	2806	45822	
8	3397	41961	3243	42893	3092	43850	2946	44831	2804	45839	22
	3394	41976	3240	42909	3090	43866	2944	44848	2801	45856	
9	3391	41991	3237	42925	3088	43882	2941	44864	2799	45873	21
	3389	42007	3235	42941	3085	43898	2939	44881	2797	45890	
10	3386	42022	3233	42956	3083	43914	2936	44898	2794	45907	20
	3384	42038	3230	42972	3080	43931	2934	44914	2792	45924	
11	3381	42053	3227	42988	3078	43947	2932	44931	2789	45941	19
	3379	42068	3225	43004	3075	43963	2929	44947	2787	45958	
12	3376	42084	3222	43020	3073	43979	2927	44964	2785	45975	18
	3373	42099	3220	43035	3070	43995	2924	44981	2782	45992	
13	3371	42115	3217	43051	3068	44012	2922	44997	2780	46009	17
	3368	42130	3215	43067	3065	44028	2920	45014	2778	46026	
14	3366	42145	3212	43083	3063	44044	2917	45031	2775	46043	16
	3363	42161	3210	43099	3060	44060	2915	45047	2773	46061	
15	3360	42176	3207	43114	3058	44077	2913	45064	2771	46078	15
	3358	42192	3205	43130	3056	44093	2910	45081	2768	46095	
16	3355	42207	3202	43146	3053	44109	2908	45097	2766	46112	14
	3353	42223	3200	43162	3051	44125	2905	45114	2764	46129	
17	3350	42238	3197	43178	3048	44142	2903	45131	2761	46146	13
	3348	42254	3195	43194	3046	44158	2901	45147	2759	46163	
18	3345	42269	3192	43210	3043	44174	2898	45164	2757	46181	12
	3342	42285	3190	43225	3041	44190	2896	45181	2755	46198	
19	3340	42300	3187	43241	3038	44207	2893	45198	2752	46215	11
	3337	42316	3185	43257	3036	44223	2891	45214	2750	46232	
20	3335	42331	3182	43273	3033	44239	2889	45231	2748	46249	10
	3332	42347	3180	43289	3031	44256	2886	45248	2745	46266	
21	3329	42362	3177	43305	3029	44272	2884	45265	2743	46284	9
	3327	42378	3175	43321	3026	44288	2881	45281	2741	46301	
22	3324	42393	3172	43337	3024	44305	2879	45298	2738	46318	8
	3322	42409	3170	43353	3021	44321	2877	45315	2736	46335	
23	3319	42424	3167	43369	3019	44337	2874	45332	2734	46353	7
	3317	42440	3165	43385	3016	44354	2872	45348	2731	46370	
24	3314	42455	3162	43400	3014	44370	2870	45365	2729	46387	6
	3312	42471	3160	43416	3012	44386	2867	45382	2727	46404	
25	3309	42486	3157	43432	3009	44403	2865	45399	2724	46422	5
	3306	42502	3155	43448	3007	44419	2862	45416	2722	46439	
26	3304	42518	3152	43464	3004	44436	2860	45433	2720	46456	4
	3301	42533	3150	43480	3002	44452	2858	45449	2717	46473	
27	3299	42549	3147	43496	2999	44468	2855	45466	2715	46491	3
	3296	42564	3145	43512	2997	44485	2853	45483	2713	46508	
28	3294	42580	3142	43528	2994	44501	2851	45500	2711	46525	2
	3291	42596	3140	43544	2992	44518	2848	45517	2708	46543	
29	3289	42611	3137	43560	2990	44534	2846	45534	2706	46560	1
	3286	42627	3135	43576	2987	44551	2844	45551	2704	46577	
30	3283	42642	3132	43592	2985	44567	2841	45567	2701	46595	0
	A	B	A	B	A	B	A	B	A	B	
	112°00'		111°30'		111°00'		110°30'		110°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	70°00'		70°30'		71°00'		71°30'		72°00'		
	A	B	A	B	A	B	A	B	A	B	
0	2701	46595	2565	47650	2433	48736	2304	49852	2179	51002	30
1	2699	46612	2563	47668	2431	48754	2302	49871	2177	51021	29
	2697	46630	2561	47686	2429	48772	2300	49890	2175	51041	
2	2694	46647	2559	47704	2427	48791	2298	49909	2173	51060	28
	2692	46664	2556	47722	2424	48809	2296	49928	2171	51080	
3	2690	46682	2554	47740	2422	48828	2294	49947	2169	51099	27
	2688	46699	2552	47758	2420	48846	2292	49966	2167	51119	
4	2685	46716	2550	47775	2418	48864	2290	49985	2165	51138	26
	2683	46734	2547	47793	2416	48883	2287	50004	2163	51158	
5	2681	46751	2545	47811	2413	48901	2285	50023	2161	51177	25
	2678	46769	2543	47829	2411	48920	2283	50042	2159	51197	
6	2676	46786	2541	47847	2409	48938	2281	50061	2157	51216	24
	2674	46804	2539	47865	2407	48957	2279	50080	2155	51236	
7	2672	46821	2536	47883	2405	48975	2277	50098	2153	51255	23
	2669	46839	2534	47901	2403	48993	2275	50117	2151	51275	
8	2667	46856	2532	47919	2400	49012	2273	50137	2149	51294	22
	2665	46873	2530	47937	2398	49030	2271	50156	2147	51314	
9	2662	46891	2528	47955	2396	49049	2269	50175	2145	51334	21
	2660	46908	2525	47973	2394	49067	2266	50194	2143	51353	
10	2658	46926	2523	47991	2392	49086	2264	50213	2141	51373	20
	2656	46943	2521	48009	2390	49104	2262	50232	2138	51392	
11	2653	46961	2519	48027	2387	49123	2260	50251	2136	51412	19
	2651	46978	2516	48045	2385	49141	2258	50270	2134	51432	
12	2649	46996	2514	48063	2383	49160	2256	50289	2132	51451	18
	2646	47014	2512	48081	2381	49179	2254	50308	2130	51471	
13	2644	47031	2510	48099	2379	49197	2252	50327	2128	51491	17
	2642	47049	2507	48117	2377	49216	2250	50346	2126	51510	
14	2640	47066	2505	48135	2375	49234	2248	50365	2124	51530	16
	2637	47084	2503	48153	2372	49253	2246	50385	2122	51550	
15	2635	47101	2501	48171	2370	49271	2243	50404	2120	51570	15
	2633	47119	2499	48189	2368	49290	2241	50423	2118	51589	
16	2631	47137	2496	48207	2366	49309	2239	50442	2116	51609	14
	2628	47154	2494	48226	2364	49327	2237	50461	2114	51629	
17	2626	47172	2492	48244	2362	49346	2235	50480	2112	51649	13
	2624	47189	2490	48262	2360	49365	2233	50499	2110	51668	
18	2622	47207	2488	48280	2358	49383	2231	50519	2108	51688	12
	2619	47225	2485	48298	2355	49402	2229	50538	2106	51708	
19	2617	47242	2483	48316	2353	49421	2227	50557	2104	51728	11
	2615	47269	2481	48334	2351	49439	2225	50576	2102	51747	
20	2613	47278	2479	48352	2349	49458	2223	50596	2100	51767	10
	2610	47295	2477	48371	2347	49477	2221	50615	2098	51787	
21	2608	47313	2474	48389	2345	49495	2218	50634	2096	51807	9
	2606	47331	2472	48407	2343	49514	2216	50653	2094	51827	
22	2604	47348	2470	48425	2340	49533	2214	50673	2092	51847	8
	2601	47366	2468	48443	2338	49551	2212	50692	2090	51867	
23	2599	47384	2466	48462	2336	49570	2210	50711	2088	51886	7
	2597	47402	2463	48480	2334	49589	2208	50730	2086	51906	
24	2594	47419	2461	48498	2332	49608	2206	50750	2084	51926	6
	2592	47437	2459	48516	2330	49626	2204	50769	2082	51946	
25	2590	47455	2457	48534	2328	49645	2202	50788	2080	51966	5
	2588	47472	2455	48553	2325	49664	2200	50808	2078	51986	
26	2585	47490	2453	48571	2323	49683	2198	50827	2076	52006	4
	2583	47508	2450	48589	2321	49702	2196	50846	2074	52026	
27	2581	47526	2448	48608	2319	49720	2194	50866	2072	52046	3
	2579	47544	2446	48626	2317	49739	2192	50885	2070	52066	
28	2576	47561	2444	48644	2315	49758	2190	50905	2068	52086	2
	2574	47579	2442	48662	2313	49777	2188	50924	2066	52106	
29	2572	47597	2439	48681	2311	49796	2185	50943	2064	52126	1
	2570	47615	2437	48699	2309	49815	2183	50963	2062	52146	
30	2568	47633	2435	48717	2306	49833	2181	50982	2060	52166	0
	2565	47650	2433	48736	2304	49852	2179	51002	2058	52186	
	A	B	A	B	A	B	A	B	A	B	
	109°30'		109°00'		108°30'		108°00'		107°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	72°30'		73°00'		73°30'		74°00'		74°30'		
	A	B	A	B	A	B	A	B	A	B	
0	2058	.52186	1940	.53406	1826	.54666	1716	.55966	1609	.57310	30
1	2056	.52206	1938	.53427	1824	.54687	1714	.55988	1607	.57333	29
	2054	.52226	1936	.53448	1823	.54708	1712	.56010	1605	.57356	
2	2052	.52246	1935	.53468	1821	.54730	1710	.56032	1604	.57378	28
	2050	.52266	1933	.52489	1819	.54751	1709	.56054	1602	.57401	
3	2048	.52286	1931	.53510	1817	.54773	1707	.56076	1600	.57424	27
	2046	.52306	1929	.53531	1815	.54794	1705	.56099	1598	.57447	
4	2044	.52326	1927	.53551	1813	.54815	1703	.56121	1597	.57470	26
	2042	.52346	1925	.53572	1811	.54837	1701	.56143	1595	.57493	
5	2040	.52366	1923	.53593	1809	.54858	1700	.56165	1593	.57516	25
	2038	.52387	1921	.53614	1808	.54880	1698	.56187	1591	.57538	
6	2036	.52407	1919	.53634	1806	.54901	1696	.56209	1590	.57561	24
	2034	.52427	1917	.53655	1804	.54922	1694	.56231	1588	.57584	
7	2032	.52447	1915	.53676	1802	.54944	1692	.56254	1586	.57607	23
	2030	.52467	1913	.53697	1800	.54965	1691	.56276	1584	.57630	
8	2028	.52487	1911	.53718	1798	.54987	1689	.56298	1583	.57653	22
	2026	.52508	1910	.53738	1796	.55008	1687	.56320	1581	.57676	
9	2024	.52528	1908	.53759	1795	.55030	1685	.56342	1579	.57699	21
	2022	.52548	1906	.53780	1793	.55051	1683	.56365	1578	.57722	
10	2020	.52568	1904	.53801	1791	.55073	1682	.56387	1576	.57745	20
	2018	.52588	1902	.53822	1789	.55095	1680	.56409	1574	.57768	
11	2016	.52609	1900	.53843	1787	.55116	1678	.56431	1572	.57791	19
	2014	.52629	1898	.53864	1785	.55138	1676	.56454	1571	.57814	
12	2012	.52649	1896	.53884	1783	.55159	1674	.56476	1569	.57837	18
	2010	.52670	1894	.53905	1782	.55181	1673	.56498	1567	.57860	
13	2009	.52690	1892	.53926	1780	.55202	1671	.56521	1565	.57884	17
	2007	.52710	1890	.53947	1778	.55224	1669	.56543	1564	.57907	
14	2005	.52730	1889	.53968	1776	.55246	1667	.56565	1562	.57930	16
	2003	.52751	1887	.53989	1774	.55267	1665	.56588	1560	.57953	
15	2001	.52771	1885	.54010	1772	.55289	1664	.56610	1559	.57976	15
	1999	.52791	1883	.54031	1771	.55311	1662	.56632	1557	.57999	
16	1997	.52812	1881	.54052	1769	.55332	1660	.56655	1555	.58022	14
	1995	.52832	1879	.54073	1767	.55354	1658	.56677	1553	.58046	
17	1993	.52852	1877	.54094	1765	.55376	1657	.56700	1552	.58069	13
	1991	.52873	1875	.54115	1763	.55397	1655	.56722	1550	.58092	
18	1989	.52893	1873	.54136	1761	.55419	1653	.56745	1548	.58115	12
	1987	.52914	1871	.54157	1760	.55441	1651	.56767	1546	.58138	
19	1985	.52934	1870	.54178	1758	.55463	1650	.56790	1545	.58162	11
	1983	.52954	1868	.54199	1756	.55484	1648	.56812	1543	.58185	
20	1981	.52975	1866	.54220	1754	.55506	1646	.56835	1541	.58208	10
	1979	.52995	1864	.54242	1752	.55528	1644	.56857	1540	.58232	
21	1977	.53016	1862	.54263	1750	.55550	1642	.56880	1538	.58255	9
	1975	.53036	1860	.54284	1749	.55572	1641	.56902	1536	.58278	
22	1973	.53057	1858	.54305	1747	.55593	1639	.56925	1534	.58302	8
	1971	.53077	1856	.54326	1745	.55615	1637	.56947	1533	.58325	
23	1969	.53098	1854	.54347	1743	.55637	1635	.56970	1531	.58348	7
	1967	.53118	1853	.54368	1741	.55659	1634	.56992	1529	.58372	
24	1966	.53139	1851	.54390	1739	.55681	1632	.57015	1528	.58395	6
	1964	.53159	1849	.54411	1738	.55703	1630	.57038	1526	.58418	
25	1962	.53180	1847	.54432	1736	.55725	1628	.57060	1524	.58442	5
	1960	.53200	1845	.54453	1734	.55746	1627	.57083	1523	.58465	
26	1958	.53221	1843	.54474	1732	.55768	1625	.57106	1521	.58489	4
	1956	.53241	1841	.54496	1730	.55790	1623	.57128	1519	.58512	
27	1954	.53262	1839	.54517	1728	.55812	1621	.57151	1517	.58536	3
	1952	.53283	1837	.54538	1727	.55834	1619	.57174	1516	.58559	
28	1950	.53303	1836	.54559	1725	.55856	1618	.57196	1514	.58583	2
	1948	.53324	1834	.54581	1723	.55878	1616	.57219	1512	.58606	
29	1946	.53344	1832	.54602	1721	.55900	1614	.57242	1511	.58630	1
	1944	.53365	1830	.54623	1719	.55922	1612	.57265	1509	.58653	
30	1942	.53386	1828	.54644	1718	.55944	1611	.57287	1507	.58677	0
	1940	.53406	1826	.54666	1716	.55966	1609	.57310	1506	.58700	
	A	B	A	B	A	B	A	B	A	B	
	107°00'		106°30'		106°00'		105°30'		105°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	75°00'		75°30'		76°00'		76°30'		77°00'		
	A	B	A	B	A	B	A	B	A	B	
0	1506	.58700	1406	.60140	1310	.61632	1217	.63181	1128	.64791	30
	1504	.58724	1404	.60164	1308	.61658	1215	.63208	1126	.64819	
1	1502	.58748	1403	.60189	1306	.61683	1214	.63234	1125	.64846	29
	1500	.58771	1401	.60213	1305	.61709	1212	.63260	1123	.64873	
2	1499	.58795	1399	.60238	1303	.61734	1211	.63287	1122	.64901	28
	1497	.58818	1398	.60262	1301	.61759	1209	.63313	1120	.64928	
3	1495	.58842	1396	.60287	1300	.61785	1208	.63340	1119	.64956	27
	1494	.58866	1394	.60311	1299	.61810	1206	.63366	1117	.64983	
4	1492	.58889	1393	.60336	1297	.61836	1205	.63392	1116	.65011	26
	1490	.58913	1391	.60360	1295	.61861	1203	.63419	1114	.65038	
5	1489	.58937	1390	.60385	1294	.61887	1202	.63445	1113	.65066	25
	1487	.58960	1388	.60410	1292	.61912	1200	.63472	1112	.65093	
6	1485	.58984	1386	.60434	1291	.61938	1199	.63498	1110	.65121	24
	1484	.59008	1385	.60459	1289	.61963	1197	.63525	1109	.65148	
7	1482	.59032	1383	.60483	1288	.61989	1196	.63551	1107	.65176	23
	1480	.59055	1381	.60508	1286	.62014	1194	.63578	1106	.65204	
8	1479	.59079	1380	.60533	1284	.62040	1193	.63605	1104	.65231	22
	1477	.59103	1378	.60557	1283	.62065	1191	.63631	1103	.65259	
9	1475	.59127	1377	.60582	1281	.62091	1190	.63658	1101	.65287	21
	1474	.59151	1375	.60607	1280	.62117	1188	.63684	1100	.65314	
10	1472	.59175	1373	.60631	1278	.62142	1187	.63711	1099	.65342	20
	1470	.59198	1372	.60656	1277	.62168	1185	.63738	1097	.65370	
11	1469	.59222	1370	.60681	1275	.62194	1184	.63764	1096	.65398	19
	1467	.59246	1368	.60706	1274	.62219	1182	.63791	1094	.65425	
12	1465	.59270	1367	.60730	1272	.62245	1181	.63818	1093	.65453	18
	1464	.59294	1365	.60755	1270	.62271	1179	.63845	1091	.65481	
13	1462	.59318	1364	.60780	1269	.62296	1178	.63871	1090	.65509	17
	1460	.59342	1362	.60805	1267	.62322	1176	.63898	1089	.65537	
14	1459	.59366	1360	.60830	1266	.62348	1175	.63925	1087	.65564	16
	1457	.59390	1359	.60855	1264	.62374	1173	.63952	1086	.65592	
15	1455	.59414	1357	.60879	1263	.62400	1172	.63978	1084	.65620	15
	1454	.59438	1356	.60904	1261	.62425	1170	.64005	1083	.65648	
16	1452	.59462	1354	.60929	1260	.62451	1169	.64032	1081	.65676	14
	1450	.59486	1352	.60954	1258	.62477	1167	.64059	1080	.65704	
17	1449	.59510	1351	.60979	1257	.62503	1166	.64086	1079	.65732	13
	1447	.59534	1349	.61004	1255	.62529	1164	.64113	1077	.65760	
18	1445	.59558	1348	.61029	1253	.62555	1163	.64140	1076	.65788	12
	1444	.59582	1346	.61054	1252	.62581	1161	.64167	1074	.65816	
19	1442	.59606	1344	.61079	1250	.62607	1160	.64194	1073	.65844	11
	1440	.59630	1343	.61104	1249	.62633	1158	.64221	1071	.65872	
20	1439	.59654	1341	.61129	1247	.62659	1157	.64248	1070	.65900	10
	1437	.59679	1340	.61154	1246	.62685	1155	.64275	1069	.65928	
21	1435	.59703	1338	.61179	1244	.62711	1154	.64302	1067	.65957	9
	1434	.59727	1336	.61204	1243	.62737	1152	.64329	1066	.65985	
22	1432	.59751	1335	.61229	1241	.62763	1151	.64356	1064	.66013	8
	1430	.59775	1333	.61254	1240	.62789	1150	.64383	1063	.66041	
23	1429	.59800	1332	.61279	1238	.62815	1148	.64410	1061	.66069	7
	1427	.59824	1330	.61304	1237	.62841	1147	.64437	1060	.66098	
24	1425	.59848	1329	.61330	1235	.62867	1145	.64464	1059	.66126	6
	1424	.59872	1327	.61355	1234	.62893	1144	.64491	1057	.66154	
25	1422	.59896	1325	.61380	1232	.62919	1142	.64518	1056	.66182	5
	1421	.59921	1324	.61405	1230	.62945	1141	.64546	1054	.66211	
26	1419	.59945	1322	.61430	1229	.62971	1139	.64573	1053	.66239	4
	1417	.59969	1321	.61456	1227	.62998	1138	.64600	1052	.66267	
27	1416	.59994	1319	.61481	1226	.63024	1136	.64627	1050	.66296	3
	1414	.60018	1317	.61506	1224	.63050	1135	.64655	1049	.66324	
28	1412	.60042	1316	.61531	1223	.63076	1133	.64682	1047	.66352	2
	1411	.60067	1314	.61556	1221	.63103	1132	.64709	1046	.66381	
29	1409	.60091	1313	.61582	1220	.63129	1130	.64736	1045	.66409	1
	1407	.60116	1311	.61607	1218	.63155	1129	.64764	1043	.66438	
30	1406	.60140	1310	.61632	1217	.63181	1128	.64791	1042	.66466	0
	A	B	A	B	A	B	A	B	A	B	
	104°30'		104°00'		103°30'		103°00'		102°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER THAN LATITUDE. IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	77°30'		78°00'		78°30'		79°00'		79°30'		
	A	B	A	B	A	B	A	B	A	B	
0	1042	.68466	960	.68212	881	.70034	805	.71940	733	.73937	30
	1040	.66495	958	.68242	879	.70065	804	.71973	732	.73971	
1	1039	.66523	957	.68272	878	.70097	803	.72005	731	.74005	29
	1038	.66552	955	.68301	877	.70128	802	.72038	730	.74039	
2	1036	.66580	954	.68331	876	.70159	800	.72070	729	.74073	28
	1035	.66609	953	.68361	874	.70190	799	.72103	728	.74107	
3	1033	.66638	951	.68391	873	.70221	798	.72136	726	.74142	27
	1032	.66666	950	.68421	872	.70252	797	.72168	725	.74176	
4	1031	.66695	949	.68460	870	.70284	796	.72201	724	.74210	26
	1029	.66724	947	.68480	869	.70315	794	.72234	723	.74245	
5	1028	.66752	946	.68510	868	.70346	793	.72266	722	.74279	25
	1026	.66781	945	.68540	867	.70377	792	.72299	721	.74313	
6	1025	.66810	943	.68570	865	.70409	791	.72332	719	.74348	24
	1024	.66838	942	.68600	864	.70440	790	.72365	718	.74382	
7	1022	.66867	941	.68630	863	.70471	788	.72397	717	.74417	23
	1021	.66896	939	.68660	862	.70503	787	.72430	716	.74451	
8	1020	.66925	938	.68690	860	.70634	786	.72463	715	.74486	22
	1018	.66953	937	.68720	859	.70566	785	.72496	714	.74520	
9	1017	.66982	935	.68750	858	.70597	783	.72529	712	.74555	21
	1015	.67011	934	.68781	856	.70629	782	.72562	711	.74589	
10	1014	.67040	933	.68811	855	.70660	781	.72595	710	.74624	20
	1013	.67069	932	.68841	854	.70692	780	.72628	709	.74659	
11	1011	.67098	930	.68871	853	.70723	779	.72661	708	.74693	19
	1010	.67127	929	.68901	851	.70755	777	.72694	707	.74728	
12	1008	.67156	928	.68931	850	.70786	776	.72727	706	.74763	18
	1007	.67185	926	.68962	849	.70818	775	.72760	704	.74797	
13	1006	.67214	925	.68992	848	.70850	774	.72794	703	.74832	17
	1004	.67243	924	.69022	846	.70881	772	.72827	702	.74867	
14	1003	.67272	922	.69053	845	.70913	771	.72860	701	.74902	16
	1002	.67301	921	.69083	844	.70945	770	.72893	700	.74937	
15	1000	.67330	920	.69113	843	.70976	769	.72926	699	.74972	15
	999	.67359	918	.69144	841	.71008	768	.72960	698	.75007	
16	997	.67388	917	.69174	840	.71040	767	.72993	696	.75042	14
	996	.67417	916	.69204	839	.71072	765	.73026	695	.75077	
17	995	.67447	914	.69235	838	.71104	764	.73060	694	.75112	13
	993	.67476	913	.69265	836	.71135	763	.73093	693	.75147	
18	992	.67505	912	.69296	835	.71167	762	.73127	692	.75182	12
	991	.67534	910	.69326	834	.71199	761	.73160	691	.75217	
19	989	.67563	909	.69357	833	.71231	759	.73193	690	.75252	11
	988	.67593	908	.69387	831	.71263	758	.73227	688	.75287	
20	987	.67622	907	.69418	830	.71295	757	.73260	687	.75322	10
	985	.67651	905	.69449	829	.71327	756	.73294	686	.75358	
21	984	.67681	904	.69479	828	.71359	755	.73328	685	.75393	9
	982	.67710	903	.69510	826	.71391	753	.73361	684	.75428	
22	981	.67739	901	.69541	825	.71423	752	.73395	683	.75464	8
	980	.67769	900	.69571	824	.71455	751	.73429	682	.75499	
23	978	.67798	899	.69602	823	.71488	750	.73462	680	.75534	7
	977	.67828	897	.69633	821	.71520	749	.73496	679	.75570	
24	976	.67857	896	.69664	820	.71552	747	.73530	678	.75605	6
	974	.67886	895	.69694	819	.71584	746	.73563	677	.75641	
25	973	.67916	894	.69725	818	.71616	745	.73597	676	.75676	5
	972	.67945	892	.69756	816	.71649	744	.73631	675	.75712	
26	970	.67975	891	.69787	815	.71681	743	.73665	674	.75747	4
	969	.68005	890	.69815	814	.71713	742	.73699	673	.75783	
27	968	.68034	888	.69849	813	.71746	740	.73733	672	.75819	3
	966	.68064	887	.69879	811	.71778	739	.73767	670	.75854	
28	965	.68093	886	.69910	810	.71810	738	.73801	669	.75890	2
	964	.68123	885	.69941	809	.71843	737	.73835	668	.75926	
29	962	.68153	883	.69972	808	.71875	736	.73869	667	.75961	1
	961	.68182	882	.70003	807	.71908	735	.73903	666	.75997	
30	960	.68212	881	.70034	805	.71940	733	.73937	665	.76033	0
	A	B	A	B	A	B	A	B	A	B	
	102°00'		101°30'		101°00'		100°30'		100°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	80°00'		80°30'		81°00'		81°30'		82°00'		
	A	B	A	B	A	B	A	B	A	B	
0	665	76033	600	78239	538	80567	480	83030	425	85644	30
1	664	76069	599	78277	537	80607	479	83072	424	85689	29
	663	76105	598	78315	536	80647	478	83114	423	85734	
2	661	76141	597	78352	535	80687	477	83157	422	85779	28
	660	76176	595	78390	534	80727	476	83199	421	85825	
3	659	76212	594	78428	533	80767	475	83242	420	85870	27
	658	76248	593	78466	532	80807	474	83284	419	85915	
4	657	76284	592	78504	531	80847	473	83327	418	85960	26
	656	76320	591	78542	530	80887	472	83369	418	86006	
5	655	76357	590	78580	529	80927	471	83412	417	86051	25
	654	76393	589	78618	528	80967	470	83455	416	86096	
6	653	76429	588	78656	527	81008	469	83497	415	86142	24
	652	76465	587	78694	526	81048	468	83540	414	86187	
7	650	76501	586	78733	525	81088	467	83583	413	86233	23
	649	76537	585	78771	524	81129	467	83626	412	86278	
8	648	76574	584	78809	523	81169	466	83668	411	86324	22
	647	76610	583	78847	522	81210	465	83711	411	86370	
9	646	76646	582	78886	521	81250	464	83754	410	86415	21
	645	76683	581	78924	520	81291	463	83797	409	86461	
10	644	76719	580	78962	519	81331	462	83840	408	86507	20
	643	76756	579	79001	518	81372	461	83884	407	86553	
11	642	76792	578	79039	517	81413	460	83927	406	86599	19
	641	76828	577	79078	516	81453	459	83970	405	86645	
12	639	76865	576	79116	515	81494	458	84013	405	86691	18
	638	76902	575	79155	514	81535	457	84056	404	86737	
13	637	76938	574	79193	513	81576	456	84100	403	86783	17
	636	76975	573	79232	512	81617	455	84143	402	86829	
14	635	77011	571	79271	511	81657	454	84186	401	86876	16
	634	77048	570	79309	510	81698	454	84230	400	86922	
15	633	77085	569	79348	509	81739	453	84273	399	86968	15
	632	77122	568	79387	508	81780	452	84317	399	87015	
16	631	77158	567	79426	507	81821	451	84361	398	87061	14
	630	77195	566	79465	506	81863	450	84404	397	87107	
17	629	77232	565	79503	505	81904	449	84448	396	87154	13
	627	77269	564	79542	504	81945	448	84492	395	87201	
18	626	77306	563	79581	504	81986	447	84535	394	87247	12
	625	77343	562	79620	503	82027	446	84579	393	87294	
19	624	77380	561	79659	502	82069	445	84623	392	87341	11
	623	77417	560	79698	501	82110	444	84667	392	87387	
20	622	77454	559	79737	500	82151	444	84711	391	87434	10
	621	77491	558	79777	499	82193	443	84755	390	87481	
21	620	77528	557	79816	498	82234	442	84799	389	87528	9
	619	77565	556	79855	497	82276	441	84843	388	87575	
22	618	77602	555	79894	496	82317	440	84887	387	87622	8
	617	77639	554	79933	495	82359	439	84931	387	87669	
23	616	77677	553	79973	494	82400	438	84976	386	87716	7
	615	77714	552	80012	493	82442	437	85020	385	87764	
24	614	77751	551	80051	492	82484	436	85064	384	87811	6
	612	77788	550	80091	491	82526	435	85109	383	87858	
25	611	77826	549	80130	490	82567	434	85153	382	87906	5
	610	77863	548	80170	489	82609	434	85197	381	87953	
26	609	77901	547	80209	488	82651	433	85242	381	88001	4
	608	77938	546	80249	487	82693	432	85286	380	88048	
27	607	77976	545	80288	486	82735	431	85331	379	88096	3
	606	78013	544	80328	485	82777	430	85376	378	88143	
28	605	78051	543	80368	484	82819	429	85420	377	88191	2
	604	78088	542	80407	483	82861	428	85465	376	88239	
29	603	78126	541	80447	482	82903	427	85510	376	88286	1
	602	78164	540	80487	482	82946	426	85555	375	88334	
30	601	78201	539	80527	481	82987	426	85599	374	88382	0
	600	78239	538	80567	480	83030	425	85644	373	88430	
	A	B	A	B	A	B	A	B	A	B	
	99°30'		99°00'		98°30'		98°00'		97°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	82°30'		83°00'		83°30'		84°00'		84°30'		
	A	B	A	B	A	B	A	B	A	B	
0	373 88430		325 91411		280 94614		238.8 ... 98076		200.4 ... 101843		30
	372 88478		324 91462		279 94670		237.9 ... 98137		199.8 ... 101908		
1	371 88526		323 91514		279 94725		237.2 ... 98197		199.2 ... 101974		29
	371 88574		323 91565		278 94781		236.8 ... 98257		198.6 ... 102040		
2	370 88623		322 91817		277 94836		235.9 ... 98318		198.0 ... 102108		28
	369 88671		321 91668		276 94892		235.3 ... 98378		197.4 ... 102172		
3	368 88719		320 91720		276 94948		234.6 ... 98439		196.8 ... 102238		27
	367 88767		319 91772		275 95004		233.9 ... 98499		196.2 ... 102304		
4	366 88816		319 91824		274 95060		233.3 ... 98560		195.6 ... 102371		26
	366 88864		318 91876		274 95116		232.6 ... 98621		195.0 ... 102437		
5	365 88913		317 91928		273 95172		232.0 ... 98682		194.4 ... 102504		25
	364 88961		318 91980		272 95228		231.3 ... 98743		193.8 ... 102570		
6	363 89010		318 92032		271 95285		230.7 ... 98804		193.2 ... 102637		24
	362 89059		315 92085		271 95341		230.0 ... 98865		192.6 ... 102704		
7	362 89107		314 92137		270 95397		229.4 ... 98926		192.0 ... 102771		23
	361 89156		313 92189		269 95454		228.7 ... 98988		191.4 ... 102838		
8	360 89205		313 92242		269 95510		228.1 ... 99049		190.8 ... 102905		22
	359 89254		312 92294		288 95567		227.4 ... 99111		190.2 ... 102973		
9	358 89303		311 92347		267 95624		226.8 ... 99172		189.6 ... 103040		21
	357 89352		310 92399		287 95681		226.1 ... 99234		189.0 ... 103107		
10	357 89401		310 92452		286 95737		225.5 ... 99296		188.4 ... 103175		20
	358 89450		309 92505		265 95795		224.8 ... 99357		187.8 ... 103243		
11	355 89499		308 92558		264 95851		224.2 ... 99419		187.2 ... 103311		19
	354 89548		307 92610		264 95909		223.5 ... 99482		188.7 ... 103379		
12	353 89597		307 92663		263 95966		222.9 ... 99544		186.1 ... 103447		18
	353 89647		306 92716		262 96023		222.3 ... 99606		185.5 ... 103515		
13	352 89696		305 92769		262 96080		221.6 ... 99668		184.9 ... 103583		17
	351 89746		304 92823		261 96138		221.0 ... 99731		184.3 ... 103651		
14	350 89795		304 92876		260 96195		220.3 ... 99793		183.7 ... 103720		16
	349 89845		303 92929		260 96253		219.7 ... 99856		183.2 ... 103788		
15	349 89894		302 92982		259 96310		219.1 ... 99918		182.6 ... 103857		15
	348 89944		301 93036		258 96368		218.4 ... 99981		182.0 ... 103926		
16	347 89994		301 93089		257 96426		217.8 ... 100044		181.4 ... 103995		14
	346 90044		300 93143		257 96484		217.2 ... 100107		180.8 ... 104064		
17	345 90093		299 93196		256 96542		216.5 ... 100170		180.3 ... 104133		13
	345 90143		298 93250		255 96600		215.9 ... 100233		179.7 ... 104202		
18	344 90193		298 93304		255 96658		215.3 ... 100296		179.1 ... 104272		12
	343 90243		297 93358		254 96716		214.6 ... 100360		178.5 ... 104341		
19	342 90293		296 93411		253 96774		214.0 ... 100423		178.0 ... 104411		11
	341 90344		295 93465		253 96833		213.4 ... 100487		177.4 ... 104480		
20	341 90394		295 93519		252 96891		212.8 ... 100550		176.8 ... 104550		10
	340 90444		294 93573		251 96950		212.1 ... 100614		176.2 ... 104620		
21	339 90494		293 93628		251 97008		211.5 ... 100678		175.7 ... 104690		9
	338 90545		292 93682		250 97067		210.9 ... 100742		175.1 ... 104760		
22	337 90595		292 93736		249 97126		210.3 ... 100806		174.5 ... 104830		8
	337 90646		291 93790		249 97184		209.6 ... 100870		174.0 ... 104901		
23	336 90696		290 93845		248 97243		209.0 ... 100934		173.4 ... 104971		7
	335 90747		289 93899		247 97302		208.4 ... 100998		172.8 ... 105042		
24	334 90798		289 93954		247 97361		207.8 ... 101063		172.3 ... 105113		6
	333 90848		288 94009		246 97420		207.1 ... 101127		171.7 ... 105183		
25	333 90899		287 94063		245 97480		206.5 ... 101192		171.1 ... 105254		5
	332 90950		287 94118		245 97539		205.9 ... 101256		170.6 ... 105325		
26	331 91001		286 94173		244 97598		205.3 ... 101321		170.0 ... 105397		4
	330 91052		285 94228		243 97658		204.7 ... 101386		169.5 ... 105468		
27	330 91103		284 94283		243 97717		204.1 ... 101451		168.9 ... 105539		3
	329 91154		284 94338		242 97777		203.5 ... 101516		168.4 ... 105611		
28	328 91205		283 94393		241 97837		202.8 ... 101581		167.8 ... 105683		2
	327 91257		282 94448		241 97897		202.2 ... 101646		167.2 ... 105754		
29	326 91308		281 94503		240 97957		201.6 ... 101712		166.7 ... 105826		1
	326 91359		281 94559		239 98017		201.0 ... 101777		166.0 ... 105898		
30	325 91411		280 94614		239 98076		200.4 ... 101843		165.6 ... 105970		0
	A	B	A	B	A	B	A	B	A	B	
	97°00'		96°30'		96°00'		95°30'		95°00'		

WHEN LHA (E OR W) IS GREATER THAN 90°, TAKE "K" FROM BOTTOM OF TABLE

	85°00'		85°30'		86°00'		86°30'		87°00'		
	A	B	A	B	A	B	A	B	A	B	
0	165.6	..105970	134.1	...110536	105.9	...115641	81.1	...121432	59.6	...128120	30
	165.0	..106043	133.6	...110616	105.5	...115732	80.7	...121536	59.2	...128241	
1	164.5	..106115	133.1	...110696	105.0	...115823	80.3	...121639	58.9	...128362	29
	163.9	..106187	132.6	...110777	104.6	...115913	79.9	...121743	58.6	...128483	
2	163.4	..106260	132.1	...110858	104.2	...116004	79.5	...121848	58.2	...128605	28
	162.8	..106333	131.6	...110939	103.7	...116096	79.2	...121952	57.9	...128727	
3	162.3	..106406	131.1	...111020	103.3	...116187	78.8	...122057	57.6	...128849	27
	161.7	..106479	130.6	...111101	102.9	...116278	78.4	...122161	57.3	...128972	
4	161.2	..106552	130.1	...111183	102.4	...116370	78.0	...122267	56.9	...129095	26
	160.6	..106625	129.6	...111264	102.0	...116462	77.6	...122372	56.6	...129218	
5	160.1	..106698	129.2	...111346	101.6	...116554	77.3	...122478	56.3	...129342	25
	159.6	..106772	128.7	...111428	101.1	...116647	76.9	...122584	56.0	...129466	
6	159.0	..106846	128.2	...111510	100.7	...116739	76.5	...122690	55.7	...129591	24
	158.5	..106919	127.7	...111592	100.3	...116832	76.1	...122796	55.3	...129716	
7	157.9	..106993	127.2	...111674	99.8	...116925	75.8	...122903	55.0	...129841	23
	157.4	..107067	126.7	...111757	99.4	...117018	75.4	...123010	54.7	...129967	
8	156.9	..107141	126.2	...111839	99.0	...117112	75.0	...123117	54.4	...130093	22
	156.3	..107216	125.8	...111922	98.5	...117205	74.6	...123225	54.1	...130219	
9	155.8	..107290	125.3	...112005	98.1	...117299	74.3	...123332	53.7	...130346	21
	155.2	..107364	124.8	...112088	97.7	...117393	73.9	...123441	53.4	...130473	
10	154.7	..107439	124.3	...112171	97.3	...117487	73.5	...123549	53.1	...130600	20
	154.2	..107514	123.8	...112255	96.8	...117581	73.2	...123657	52.8	...130728	
11	153.6	..107589	123.4	...112338	96.4	...117676	72.8	...123766	52.5	...130856	19
	153.1	..107664	122.9	...112422	96.0	...117771	72.4	...123875	52.2	...130985	
12	152.6	..107739	122.4	...112506	95.6	...117866	72.1	...123985	51.9	...131114	18
	152.1	..107814	121.9	...112590	95.2	...117961	71.7	...124095	51.6	...131243	
13	151.5	..107890	121.5	...112674	94.7	...118056	71.3	...124204	51.3	...131373	17
	151.0	..107965	121.0	...112759	94.3	...118152	71.0	...124315	51.0	...131503	
14	150.5	..108041	120.5	...112843	93.9	...118248	70.6	...124425	50.7	...131633	16
	149.9	..108117	120.1	...112928	93.5	...118344	70.3	...124536	50.3	...131764	
15	149.4	..108193	119.6	...113013	93.1	...118440	69.9	...124647	50.0	...131896	15
	148.9	..108269	119.1	...113098	92.7	...118537	69.5	...124759	49.7	...132027	
16	148.4	..108345	118.7	...113183	92.3	...118633	69.2	...124870	49.4	...132159	14
	147.8	..108421	118.2	...113269	91.8	...118730	68.8	...124982	49.1	...132292	
17	147.3	..108498	117.7	...113354	91.4	...118827	68.5	...125094	48.8	...132425	13
	146.8	..108574	117.3	...113440	91.0	...118925	68.1	...125207	48.5	...132558	
18	146.3	..108651	116.8	...113526	90.6	...119022	67.8	...125320	48.2	...132692	12
	145.8	..108728	116.3	...113612	90.2	...119120	67.4	...125433	47.9	...132826	
19	145.2	..108805	115.9	...113699	89.8	...119218	67.1	...125546	47.6	...132961	11
	144.7	..108882	115.4	...113785	89.4	...119316	66.7	...125660	47.3	...133096	
20	144.2	..108960	114.9	...113872	89.0	...119415	66.4	...125774	47.1	...133231	10
	143.7	..109037	114.5	...113958	88.6	...119513	66.0	...125888	46.8	...133367	
21	143.2	..109115	114.0	...114045	88.2	...119612	65.7	...126003	46.5	...133503	9
	142.7	..109192	113.6	...114133	87.8	...119711	65.3	...126118	46.2	...133640	
22	142.2	..109270	113.1	...114220	87.4	...119811	65.0	...126233	45.9	...133777	8
	141.6	..109348	112.7	...114307	87.0	...119910	64.6	...126349	45.6	...133914	
23	141.1	..109426	112.2	...114395	86.6	...120010	64.3	...126465	45.3	...134052	7
	140.6	..109505	111.7	...114483	86.2	...120110	63.9	...126581	45.0	...134191	
24	140.1	..109583	111.3	...114571	85.8	...120211	63.6	...126697	44.7	...134330	6
	139.6	..109662	110.8	...114659	85.4	...120311	63.3	...126814	44.4	...134469	
25	139.1	..109740	110.4	...114747	85.0	...120412	62.9	...126931	44.2	...134609	5
	138.6	..109819	109.9	...114836	84.6	...120513	62.6	...127049	43.9	...134749	
26	138.1	..109898	109.5	...114925	84.2	...120614	62.2	...127166	43.6	...134890	4
	137.6	..109978	109.0	...115014	83.8	...120715	61.9	...127284	43.3	...135031	
27	137.1	..110057	108.6	...115103	83.4	...120817	61.6	...127403	43.0	...135173	3
	136.6	..110136	108.1	...115192	83.0	...120919	61.2	...127521	42.7	...135315	
28	136.1	..110216	107.7	...115282	82.6	...121021	60.9	...127640	42.5	...135457	2
	135.6	..110296	107.3	...115371	82.2	...121124	60.6	...127760	42.2	...135600	
29	135.1	..110375	106.8	...115461	81.9	...121226	60.2	...127880	41.9	...135744	1
	134.6	..110455	106.4	...115551	81.5	...121329	59.9	...128000	41.6	...135888	
30	134.1	..110536	105.9	...115641	81.1	...121432	59.6	...128120	41.4	...136032	0
	A	B	A	B	A	B	A	B	A	B	
	94°30'		94°00'		93°30'		93°00'		92°30'		

ALWAYS TAKE "Z" FROM BOTTOM OF TABLE, EXCEPT WHEN "K" IS SAME NAME AND GREATER
THAN LATITUDE, IN WHICH CASE TAKE "Z" FROM TOP OF TABLE

	87°30'		88°00'		88°30'		89°00'		89°30'		
	A	B	A	B	A	B	A	B	A	B	
0	41.4	136032	26.5	145718	14.9	158208	6.6	175814	1.7	205916	30
1	41.1	136177	26.2	145899	14.7	158450	6.5	176178	1.6	206646	29
	40.8	136322	26.0	146081	14.6	158693	6.4	176544	1.5	207388	
2	40.5	136468	25.8	146264	14.4	158938	6.3	176914	1.5	208143	28
	40.3	136615	25.6	146448	14.2	159184	6.2	177287	1.4	208912	
3	40.0	136761	25.4	146632	14.1	159431	6.1	177663	1.4	209695	27
	39.7	136909	25.2	146817	13.9	159680	6.0	178042	1.3	210491	
4	39.4	137057	24.9	147003	13.7	159930	5.9	178424	1.3	211303	26
	39.2	137205	24.7	147190	13.6	160182	5.8	178810	1.2	212130	
5	38.9	137354	24.5	147377	13.4	160435	5.7	179200	1.2	212974	25
	38.6	137503	24.3	147566	13.3	160690	5.6	179593	1.1	213834	
6	38.4	137653	24.1	147755	13.1	160946	5.5	179990	1.1	214711	24
	38.1	137804	23.9	147945	13.0	161204	5.4	180390	1.1	215607	
7	37.8	137955	23.7	148135	12.8	161463	5.3	180794	1.0	216521	23
	37.6	138106	23.5	148327	12.7	161724	5.2	181201	1.0	217455	
8	37.3	138258	23.3	148520	12.5	161986	5.1	181613	0.9	218409	22
	37.1	138411	23.1	148713	12.4	162250	5.0	182029	0.9	219385	
9	36.8	138564	22.8	148907	12.2	162516	4.9	182448	0.9	220384	21
	36.5	138718	22.6	149103	12.1	162783	4.8	182872	0.8	221406	
10	36.3	138872	22.4	149299	11.9	163052	4.7	183300	0.8	222452	20
	36.0	139027	22.2	149495	11.8	163322	4.6	183732	0.7	223525	
11	35.8	139182	22.0	149693	11.6	163594	4.5	184168	0.7	224624	19
	35.5	139338	21.8	149892	11.5	163868	4.4	184609	0.7	225752	
12	35.3	139494	21.6	150092	11.3	164144	4.3	185055	0.6	226910	18
	35.0	139651	21.4	150292	11.2	164422	4.2	185505	0.6	228100	
13	34.7	139809	21.2	150494	11.0	164701	4.1	185959	0.6	229324	17
	34.5	139967	21.0	150696	10.9	164982	4.1	186419	0.5	230583	
14	34.2	140125	20.8	150899	10.8	165265	4.0	186883	0.5	231879	16
	34.0	140283	20.6	151104	10.6	165550	3.9	187353	0.5	233215	
15	33.7	140445	20.5	151309	10.5	165836	3.8	187827	0.4	234594	15
	33.5	140605	20.3	151515	10.3	166125	3.7	188307	0.4	236018	
16	33.2	140766	20.1	151722	10.2	166415	3.6	188793	0.4	237491	14
	33.0	140928	19.9	151931	10.1	166708	3.6	189283	0.4	239015	
17	32.8	141090	19.7	152140	9.9	167002	3.5	189780	0.3	240594	13
	32.5	141253	19.5	152350	9.8	167298	3.4	190282	0.3	242233	
18	32.3	141417	19.3	152561	9.7	167597	3.3	190790	0.3	243936	12
	32.0	141581	19.1	152774	9.5	167897	3.2	191303	0.3	245709	
19	31.8	141745	18.9	152987	9.4	168200	3.2	191824	0.2	247558	11
	31.5	141911	18.7	153201	9.3	168505	3.1	192350	0.2	249488	
20	31.3	142077	18.6	153417	9.1	168811	3.0	192883	0.2	251508	10
	31.1	142243	18.4	153633	9.0	169121	2.9	193422	0.2	253627	
21	30.8	142411	18.2	153851	8.9	169432	2.9	193969	0.2	255855	9
	30.6	142579	18.0	154070	8.7	169745	2.8	194522	0.1	258203	
22	30.4	142747	17.8	154290	8.6	170061	2.7	195082	0.1	260685	8
	30.1	142916	17.6	154511	8.5	170379	2.7	195650	0.1	263318	
23	29.9	143086	17.5	154733	8.4	170700	2.6	196225	0.1	266121	7
	29.6	143257	17.3	154956	8.2	171023	2.5	196808	0.1	269118	
24	29.4	143428	17.1	155180	8.1	171348	2.4	197399	0.1	272336	6
	29.2	143600	16.9	155406	8.0	171676	2.4	197998	0.1	275812	
25	28.9	143773	16.8	155633	7.9	172006	2.3	198605	0.1	279591	5
	28.7	143946	16.6	155861	7.8	172339	2.3	199221	0.0	283730	
26	28.5	144120	16.4	156090	7.6	172674	2.2	199846	0.0	288306	4
	28.3	144295	16.2	156320	7.5	173012	2.1	200480	0.0	293421	
27	28.0	144470	16.1	156552	7.4	173352	2.1	201124	0.0	299221	3
	27.8	144646	15.9	156784	7.3	173696	2.0	201777	0.0	305915	
28	27.6	144823	15.7	157019	7.2	174042	1.9	202440	0.0	313833	2
	27.4	145000	15.6	157254	7.1	174391	1.9	203113	0.0	323524	
29	27.1	145179	15.4	157490	6.9	174742	1.8	203797	0.0	336018	1
	26.9	145358	15.2	157728	6.8	175097	1.8	204492	0.0	353627	
30	26.7	145538	15.1	157967	6.7	175454	1.7	205198	0.0	383730	0
	26.5	145718	14.9	158208	6.6	175814	1.7	205916	0.0		
	A	B	A	B	A	B	A	B	A	B	
	92°00'		91°30'		91°00'		90°30'		90°00'		



1

2

3



4

5



GLOSSARY

A

Amplification—The process of increasing the electrical strength of a signal.

Antenna—An electrical conductor or a system of conductors used to radiate or receive radio waves.

Array (Antenna)—An arrangement of antenna elements to achieve desirable directional characteristics.

B

Basepoint—Any point on the earth's surface whose exact location is known by grid coordinates and over which (while airborne) accuracy adjustments to Doppler radar navigational systems may be made.

Bearing—The angular measurement in degrees from true north of an arriving radio wave with relation to the DF site. A bearing is often called a "shot."

Bidirectional—Responsive in two opposite directions. An ordinary loop antenna is bidirectional because it has maximum response from the two opposite directions that are in the plane of the loop.

C

Checkpoint—The exact location of an ARDF aircraft over the ground, identified by grid coordinates, when a DF bearing is obtained from that aircraft.

Coaxial cable—A transmission line consisting of two conductors, one inside the other, and separated by insulating material. The inner conductor may be a small copper tube or wire; the outer conductor may be metallic tubing or braid. Radiation loss from this type of line is practically zero. Coaxial cable is also called concentric line.

Conductivity—The relative ability of a material to allow the flow or passage of an electrical current.

Counterpoise—(1) A system of wires and other conductors that is elevated above and insulated from the ground to form a lower system of conductors for a transceiver antenna. (2) A system which is electrically connected to earth and positioned beneath receiving antenna elements, such as the wire mesh screens used with the AN/TRD-15 direction finder set.

Critical angle—The smallest angle from the vertical at which a radiated wave of a given frequency will still be reflected by the ionosphere. At smaller angles the radio waves penetrate the ionosphere and are not returned to earth.

Cut—The point of intersection of two DF bearings.

D

Dead reckoning—Determination of the approximate position of a vehicle by combining vectors for speed, direction, and other factors with the last known position.

Directional antenna—An antenna which radiates or receives radio waves more effectively in some directions than others. The term is usually applied to antennas whose directivity is greater than that of a half-wave dipole.

DF fix—The probable location of a target transmitter's antenna when three or more DF bearings have been plotted on a chart or map. Sometimes called a fix area.

DF plot (plotting)—The placing of DF bearings on a chart or map so that a target's location can be determined by reference to grid coordinates.

Direct path—A path that has no intervening obstacles and is said to be line-of-sight.

E

E region—The region of the ionosphere, between about 88 and 156 kilometers above the surface of the earth, that contains ionized layers capable of bending (reflecting or refracting) radio waves.

Electromagnetic field—The magnetic field that an electric current produces around the conductor through which it flows.

F

F region—The region of the ionosphere between about 200 and 310 kilometers above the earth's surface.

F1 layer—One of the regular ionospheric layers at an average height of about 225 kilometers which occurs during the daylight hours.

F2 layer—The most useful of the ionospheric layers for radio wave propagation. It is the most highly ionized and highest of the layers, having an average height of 225 kilometers and a midday height of about 400 kilometers.

Fading—Variations in the strength of a received radio signal caused by changes in the characteristics of the propagation or transmission medium.

Frequency—The number of complete cycles per second (Hertz) existing in any form of electrical or sound wave motions.

G

Goniometer—An instrument for measuring angles. Used to calculate and resolve mathematical problems or electrical functions as well as to establish direction phase difference between transmitted or received signals.

Great circle—Any circle described on the surface of the earth or other sphere so that its plane passes through the center of the sphere. Radio waves follow great-circle routes in their passage around the earth.

H

Hop—The path of a radio wave from the earth to the ionosphere and back to earth, in traveling from one point to another. It is usually used in expressions such as single hop, double hop, and multihop. The number of hops is called the order of reflection.

I

Indirect path—Any path, other than a direct path, between two stations.

Interference—Any electrical disturbance from a different source which causes undesirable responses in electronic equipment.

O

Octantal error—The erroneous reading of an arriving signal caused by the nonuniformity of the flux fields within the stationary winding of a goniometer (when used in DF sites).

P

Path—That part of the atmosphere through which the radiated wave passes.

Polarity—An electrical condition determining the direction in which current tends to flow. By common usage, the discharge current is said to flow from the positive electrode through the external circuit.

Polarization—The direction of the electrical field component of radiated energy.

R

Radiate—To send out energy into space, as in the case of RF waves.

S

Siting—Properly locating an antenna, radio set, or DF set to obtain optimum performance.

Skip distance—The minimum separation at which radio waves of a specified frequency can be transmitted at a specified time between two points on the earth by reflection from the regular ionized layers of the ionosphere.

Skywave—A radio wave that reaches the receiving station after returning from the ionosphere (as distinguished from groundwave).

W

Winding—One or more turns of wire forming a continuous coil for a transformer, relay, rotating machine, antenna, or other electrical device.

INDEX

	Paragraph	Page
A		
Abnormal		
Effects of the troposphere	2-15	2-12
Polarization	3-2 <i>d</i> , 3-8 <i>b</i> (3)	3-4, 3-19
Adcock antennas	3-8	3-18
Errors	3-9	3-22
Advantage of		
Gnomonic projection	5-4 <i>b</i>	5-4
Mercator projections with DF	5-4 <i>a</i>	5-3
Aeronautical charts	5-5	5-4
Aircraft employed in ARDF	4-13	4-10
Airborne DF site	4-11	4-10
Airborne radio direction finding	4-1 <i>c</i> , 4-11	4-1, 4-10
Airplane effect for loop error	3-5 <i>c</i> (3)	3-14
Ambiguity		
Resolution	3-3	3-4
With loop antennas	3-2 <i>e</i>	3-4
Amplitude of signal in loop antenna	3-2	3-2
Antenna		
Balance adjustment	3-5	3-12
Capacitance	3-5 <i>d</i> (4)	3-16
Effect	3-5 <i>a</i>	3-12
Antennas and radio propagation, TM 11-666	2-1	2-1
ARDF equipment	4-14	4-10
ARDF navigational requirements	4-17	4-11
ARDF report	4-20	4-11
Aural indicators	3-21 <i>a</i>	3-34
Aural null	3-21	3-34
Automatic bearing-seeking indicators	3-20 <i>c</i> (3), 3-23	3-34, 3-37
B		
Balance adjustment for antenna effects	3-5 <i>a</i> (3)	3-12
Balance in loop construction	3-6 <i>a</i>	3-16
Baseline considerations	4-4	4-7
Baseline, DWDF effort	4-3	4-6
Baseline, SWDF effort	4-10	4-10
Baseline, plotting	5-24	5-17
Basic net requirements for DF communications	6-4	6-2
Bearing		
Indicators	3-20	3-34
Reports	6-2 <i>e</i>	6-1
Seeking type indicators	3-23	3-37
Behavior of electrical waves	2-2	2-1
Border coordinates	7-2	7-1
C		
Callsign, frequency, mission information	6-2 <i>a</i>	6-1
Capacitive goniometer	3-17 <i>b</i>	3-31

	Paragraph	Page
Cardioid		
Response of antenna	3-4a	3-6
Theory	3-4	3-6
Cathode-ray tube indicators	3-22	3-35
Cause of antenna effect	3-5a(2)	3-12
Changes to manual	1-3	1-1
Characteristics		
Of bearing indicators	3-20, 3-21, 3-22, 3-23	3-34, 3-35, 3-37
Circular		
Loop antenna	3-2	3-2
Polarization	2-9b	2-6
Response of sense antenna	3-5b	3-13
Coaxial spaced-loop antennas	3-11	3-24
Combination winding-loop antennas	3-5d(5)	3-16
Comments on manual	1-3	1-1
Communications requirements for DF nets	6-1	6-1
Comparison of DWDF and SWDF site establishment	5-11	5-9
Compass Rose	5-6b	5-6
Concept of warfare	1-4	1-1
Conductivity, soil	2-16	2-13
Cone and cylinder developable surfaces	5-2b	5-1
Construction requirements for goniometers	3-17c	3-31
Contents of airborne DF site	4-11	4-10
Corrected Compass Rose (CCR)	7-3	7-1
Coupled H-Adcock antenna	3-8c(5)	3-20
Coupling systems for DF equipment	3-15	3-27
Crew requirements, ARDF aircraft	4-15	4-11
Crossed-Adcock antennas	3-10	3-23
Crossed-loop antennas	3-7	3-17
Cross reference formula, frequency to meters	2-5b	2-5
Cross reference formula, meters to wavelength	2-5b	2-5
CRT indicators	3-22	3-35
Cryptoprotection on DF net communications	6-1, 6-2e	6-1
Curve, sine	2-4	2-3
Cut	5-22b, 5-23b	5-15
CW and AM radio transmitters and receivers	2-1	2-1

D

D-layer ionosphere	2-12	2-8
DA Form 2028	1-3	1-1
Daily Check of DF accuracy	5-14b	5-11
Declination		
Definition of	5-7b	5-7
Diagrams	5-7a	5-7
Deduction relating to probable target locations	5-29	5-21
Deployment of ARDF companies	4-12	4-10
Derivation of reference points on a sphere	5-3a	5-2
Determination of fix areas	5-28	5-18
Developable surfaces for map making	5-2b	5-1
Dielectric constant of air	2-14	2-10
Diffraction	2-19	2-15
Direct coupling systems	3-16a	3-280
Direction finding		
Accuracy check	5-14	5-11
Errors	5-15	5-11
Plotting	5-22, 5-23	5-15

	Paragraph	Page
Receivers	3-24	3-38
Theory	1-5	1-1
Distance requirements for site installation	5-10h	5-9
Doppler DF	3-12	3-25
DWDF site installation	4-2	4-1

E

E-layer ionosphere	2-12	2-8
Earth's axis	5-3a	5-2
Effective distance for line-of-sight transmissions	2-21	2-18
Efficiency of conductors in transmission lines	3-15b	3-27
Electrical		
Components of radio waves	2-2	2-1
Field	2-3	2-3
Phenomena	2-10	2-8
Electronic goniometer systems	3-18	3-33
Electronic warfare support measures	1-6c	1-2
Electrostatic shield in loop constructions	3-6b	3-17
Elements within radio waves	2-2, 2-3	2-1, 2-3
Elevated H-Adcock antenna	3-8c(4)	3-20
Elliptical polarization	2-9c	2-7
Environmental ARDF considerations	4-18	4-11
Equator	5-3a	5-2
Equatorial projection	5-4c	5-4
Error triangle solution	5-28	5-18
Errors caused by reradiation	4-2b	4-1
Establishing		
Meridians of longitude	5-3a(2)	5-2
Parallels of latitude	5-3a(3)	5-2
Establishment of baseline for DWDF effort	4-3	4-6
Evaluation		
Of results by operator	5-26	5-18
Of results by plotter	5-27	5-18
Exposure to sun causing ionization	2-12	2-8
Extremely High Frequency (EHF)	2-1	2-1

F

F-layer ionosphere	2-12	2-8
F1-layer ionosphere	2-12b	2-9
Factors affecting ionospheric action	2-12	2-8
Fading or variable field intensity	2-14c	2-11
Field pattern site testing	5-12a(2)	5-9
Fix	5-22c, 5-23c	5-15
Flight environment for ARDF operations	4-19	4-11
FM communications links	2-21	2-18
Formation of tropospheric ducts	2-15	2-12
Frequency	2-5a	2-3
Band designators	2-1a	2-1
Modulation	2-21	2-18

G

Gnomonic projections	5-4b	5-4
Goniometer	3-7b	3-17
Electronic capacitive	3-17b	3-31
Inductive	3-17a	3-31

	Paragraph	Page
Pattern presentations	3-18	3-33
Great circles	5-3a	5-2
Great Circle Azimuth and Distance (GCAD)	7-4	7-5
Ground conductivity in DF sites	5-10e	5-8
Ground-reflected waves	4-2c(2)	4-4
Grounded H-Adcock antenna	3-8c(3)	3-19
Groundwave	2-11a	2-8

H

H-Adcock antenna construction	3-8a, c	3-17, 3-19
Heaviside, physicist, ionospheric studies	2-12a	2-8
Heights of ionospheric layers	2-12	2-8
Hertz (Hz)	2-5	2-3
High Frequency (HF)	2-1	2-1
Homing with DF equipment	2-22	2-18
Horizontal		
Polarization	2-6, 2-8	2-5
Polarization with Adcock antenna	3-8b	3-18
Humidity and density for tropospheric channeling	2-14b	2-11

I

Identification by tracking practices	6-2e	6-1
Improvements of DF sites	5-13	5-10
Incorrect azimuths due to loop errors	3-5	3-12
Induced voltages in loop antennas	3-2a	3-3
Inductive goniometers	3-17a	3-31
Influence of soil conductivity	2-16	2-13
Initial problem of map projection	5-3b	5-3
Instantaneous indicators	3-22	3-35
Instrument		
Adjustment	5-14	5-11
Calibration	5-14	5-11
Error	5-20	5-15
Interpretation of DF results	5-31	5-22
Intersection		
Of angle bisectors	5-28b	5-19
Of medians in error solution	5-28a	5-19
Ionized gases above the surface	2-11b	2-8
Ionosphere	2-12	2-8
Ionospheric		
Layers	2-12b	2-9
Predictions	2-12d	2-10
Isothermal region	2-13	2-10

K

Kennely, physicist, ionospheric studies	2-12a	2-8
---	-------	-----

L

Layer, combination, ionospheric	2-12c	2-9
Limitations of baseline establishment, DWDF	4-7	4-9
Line bearing	5-22a, 5-23a	5-15
Linear polarization	2-9a	2-5
Lines and coupling devices for goniometers	3-17d	3-33
Logical application of probable target locations	5-29	5-21
Loop and sense antennas	3-2, 3-3	3-2, 3-4

	Paragraph	Page
Loop		
Antenna application	3-2, 3-3b	3-2, 3-6
Construction	3-6	3-16
Errors	3-5	3-12
Patterns	3-2	3-2
Size	3-6c	3-17
Lopsided pattern of sense antenna combined	3-3	3-4
Low Frequency (LF)	2-1	2-1
M		
Magnetic components of radio waves	2-3	2-3
Magnetic field	2-3	2-3
Magnetic variation	5-6a	5-6
Manager of DF resources	6-3	6-2
Map		
Definition of	5-2a	5-1
Equatorial projection	5-4c	5-4
Gnomonic projection	5-4b	5-4
Making factors	5-2b	5-1
Reconnaissance for DWDF sites	4-8	4-9
Transverse Mercator projection	5-4a	5-3
Masking of transmitters to DWDF effort	4-6	4-8
Means of communications within DF nets	6-1	6-1
Mechanization of DF plotting	5-31	5-22
Medium Frequency (MF)	2-1	2-1
Mercator projection	5-4a	5-3
Meridians	5-3a(1)	5-2
Meridians of longitude	5-3a(2)	5-2
Method		
Of reducing path error	5-17e	5-13
Of reducing polarization error	5-18b	5-14
Used to determine probable target locations	5-28	5-18
MF/HF range, surfacewave DF effort	4-2c(3)	4-5
Mirror action reflection	2-17	2-15
Mission		
Assignment	6-3	6-2
Information for DF targets	6-2a, b, c	6-1
Of ARDF resources	4-12	4-10
Multihop transmission	2-20	2-17
Multiple bearings on targets	5-30	5-22
N		
Net requirements for DF support	6-4	6-2
Night effect		
To cause loop errors	3-5c(1)	3-14
Noise measurement, site testing	5-12a(1)	5-9
Nonnuclear warfare	1-4	1-1
Northern Hemisphere	5-3a	5-2
O		
Octantal errors with goniometers	3-19	3-33
Operations area for ARDF units	4-18	4-11
Operator		
Changes influencing plotting	5-27	5-18
Errors	5-21	5-15

	Paragraph	Page
Evaluation	5-26	5-18
Orientation of DF equipment	5-8	5-7
Other abnormal polarizations	3-8b(3)	3-18

P

Parallax or optical distortion	2-17	2-15
Parallels of latitude	5-3a(3)	5-2
Path error	5-17	5-11
Pattern		
With abnormal polarization	3-2d	3-4
With normal polarization	3-2c	3-3
Penetration of ionosphere	2-11b, 2-12	2-8
Phase voltage in loop antennas	3-2	3-2
Plane		
Polar diagram of radio wave	3-1	3-1
Polarization	2-9	2-5
Plotter evaluation	5-27	5-18
Polar		
Diagram of antennas	3-1	3-1
Reference on maps	5-3	5-1
Polarity	2-2b	2-1
Polarization		
Causing loop errors	3-5c	3-14
Circular	2-9b	2-6
Error	5-18	5-14
Errors with spaced-loop antennas	3-11d	3-25
Linear	2-9a	2-5
Of oceanwaves	2-7	2-5
Of radio waves	2-6	2-5
Of surfacewaves	4-2c(3)(c)	4-5
Positive Charge	2-2	2-1
Principle of the Adcock antenna	3-8b	3-18
Problems of control of DF nets	6-2	6-1
Propagation		
Factors	2-10	2-8
Of electromagnetic waves	2-1	2-1
Purpose		
Of manual	1-1	1-1
Of sense antenna	3-3a	3-4

Q

Quasi-Doppler DF	3-13	3-26
----------------------------	------	------

R

Radio horizons in ARDF operations	4-12	4-10
Receivers, DF	3-24	3-38
Recombination of ionosphere	2-12	2-8
Reflection	2-17	2-15
Refraction		
Definition of	2-11b, 5-17b	2-8, 5-12
Of radio waves	2-14a, 2-18	2-10, 2-15
Reliability of plotting and fix production	5-26	5-18
Requests for DF support	6-2e, 6-3	6-1, 6-2

	Paragraph	Page
Reradiation	5-17d	5-12
Reradiation for DWDF efforts	4-2b	4-1
Response pattern, crossed-loop antennas	3-7a	3-17
Right-triangle method	7-3b	7-1
Rotating		
Capacitor coupling	3-16b(2)(c)	3-30
Transformer coupling	3-16b(2)(b)	3-30
Rotation of loop antenna to vary response	3-2	3-2

S

Scatter	2-14b, 5-17a	2-11, 5-11
Scope	1-2	1-1
Searching by operators on DF sites	6-2a	6-1
Secure voice nets for DF communications	6-1	6-1
Selection of map projection types for DF	5-4	5-3
Shielded U-Adcock antenna	3-8c(2)	3-19
Shielding and grounding to remedy antenna effect	3-5a(4)	3-12
Signal Intelligence	1-6b	1-2
Simple U-Adcock antenna	3-8c(1)	3-19
Sine curve	2-4	2-3
Single site DF efforts, tactical support	6-2e	6-1
Site		
Criteria	5-10	5-8
Errors equated to plotting	5-19	5-15
Testing	5-12	5-9
Siting errors in DF installations	5-9	5-8
Skewness in loop antennas	3-5d(3)	3-15
Skip		
Distance	2-20	2-17
Zone	2-20	2-17
Skywave direction finding	4-1b, 4-9	4-1, 4-10
Skywaves	2-11b	2-8
Slip ring coupling systems	3-16b(2)(a)	3-30
Soil conductivity	2-16	2-13
Source error	5-16	5-11
Southern Hemisphere	5-3a	5-2
Spaced-loop antennas	3-11	3-24
Spacing with crossed-Adcock antennas	3-10b	3-24
Spiral pancake winding of loop antennas	3-5d(2)	3-15
Square loop antennas	3-2	3-2
Square root	7-10	7-13
Standard Deviation (SD)	7-11	7-14
Statistical factors	7-11	7-14
Steiner point method of error solution	5-28c	5-19
Stratosphere	2-13	2-10
Stretching or tearing developable surfaces	5-2b	5-1
Super High Frequency (SHF)	2-1	2-1
Surfacewave	4-2c(3)	4-5
SWDF site factors	4-9	4-10
Symmetrical pancake winding of loop antennas	3-5d(1)	3-15
Systematic Error (SE)	7-8	7-11

T

Tactical requirements for site testing	5-12b	5-9
Taking an azimuth with spaced-loop antennas	3-11e	3-25

	Paragraph	Page
Target location, determination of	5-28, 5-29	5-18, 5-21
Targets in DF missions	4-12, 5-22, 6-2	4-10, 5-15, 6-1
Tasking and reporting of DF facilities	6-2e	6-1
Tasking assignment	6-3	6-2
Tasking authority	6-3	6-2
Tasking of ARDF resources	4-12	4-10
Technical improvement of DF sites	5-13	5-10
Techniques to overcome antenna effect	3-5a	3-12
Teletypewriter communications in DF nets	6-1a, b	6-1
Temperature inversion	2-15	2-12
Template, Steiner point evaluation method	5-28c	5-19
Terrain regarding Adcock antenna errors	3-9a	3-22
Terrain, surfacewave	4-2c(3)(b)	4-5
Three-station fix, error triangle	5-28	5-18
Tilting Adcock antenna	3-8d	3-20
Transmission line coupling	3-16b	3-30
Transmission lines with antennas	3-14	3-27
Transverse Mercator projections	5-4a	5-3
Transverse wave motion	2-9	2-5
Triangle		
Bisection of angles	5-28b	5-19
Bisection of medians	5-28a	5-19
Troposphere	2-14	2-10
Tropospheric		
Bounce	2-14a	2-10
Duct	2-15	2-12
Height above earth	2-14	2-10
Scatter	2-14	2-10
Types of		
Adcock antennas	3-8c	3-19
DF communications	6-1b	6-1
DF effort	4-1	4-1
Directional antennas	3-2, 3-8, 3-9	3-2, 3-17, 3-22
Radio waves	2-11	2-8
Windings in loop antennas	3-5d	3-14
Typical ARDF equipment installations	4-14	4-10

U

U-Adcock antenna	3-8	3-17
UHF transmissions	2-23	2-19
Ultrahigh Frequency (UHF)	2-1	2-1
Ultraviolet rays	2-12	2-8
Undulating waves	2-7	2-5
Universal Mercator projection	5-4a	5-3
Use of		
Map projection with DF	5-1, 5-4, 5-5	5-1, 5-3, 5-4
The compass rose	5-6	5-5
The goniometer with crossed-loop	3-7b	3-17

V

Variance	7-9	7-12
Varying		
Height of ionospheric waves	2-12	2-8
Ionization	2-12	2-8
Vertical		
Polarization	2-7	2-5
Polarization with Adcock antennas	3-8b(1)	3-18
Vertically polarized waves	2-7	2-5
Very High Frequency (VHF)	2-1	2-1
Very Low Frequency (VLF)	2-1	2-1
VHF transmission	2-21	2-18
Visual inspection	5-28d	5-19
Visual null	3-22	3-35
Voice nets, planning range	2-21	2-18

W

Wave front cross section	2-16	2-13
Waveguide action with tropospheric transmissions	2-15	2-12
Wavelength	2-4	2-3
Wavepath considerations DWDF effort	4-5	4-7
Wave propagation theory	2-1	2-1
Waves lost for communications	2-11b	2-8
Weak signal causing loop errors	3-5b	3-13
Whip antenna	2-6	2-5
Winding arrangement of loop antennas	3-5d	3-14



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2
3



4



8 APRIL 1977

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